PROCEEDINGS

OF THE

ROYAL SOCIETY OF VICTORIA

NEW SERIES
VOLUME 78

ROYAL SOCIETY'S HALL
9 VICTORIA STREET, MELBOURNE, C.1

1965

CONTENTS OF VOLUME 78

PART 1

(4 March 1965)

PART 2

(11 June 1965)

Papers accepted for publication by the Society during 1964 and edited under the authority of the Council. The authors of the several papers are individually responsible for the accuracy of the statements made and the soundness of the opinions given therein.

DESCRIPTION AND AGE SIGNIFICANCE OF *M. HERCYNICUS* TYPE MONOGRAPTIDS FROM EILDON, VICTORIA

By William B. N. Berry

Museum of Palaeontology, University of California, Berkeley

Abstract

Monograptids of the *M. hercynicus* type have been recovered from the lowest part of the Wilson's Creek Shale and possibly the stratigraphically highest part of the Eildon Group on the slopes of Mt Sugarloaf at Eildon, Victoria. The monograptids found are assignable to two distinct forms, one of which may only be a highly distorted version of the other. The undistorted form is a new species. It was found in beds at the same stratigraphic level with those bearing *Baragwanathia* and also in those bearing hyolithids at a higher stratigraphic level. The same new species is being described by Jaeger from the *Baragwanathia*-bearing beds at the well-known 19 Mile Quarry locality on the Yarra Track.

Monograptids of the *M. hercynicus* type are at present known to occur only in strata of post-Ludlow age. The new species found at Eildon is considered to be indicative of a Gedinne age. Whether the Gedinne Stage belongs in the Silurian or Devonian System is a matter of

---

Proc. Roy. Soc. Vict. Vol. 77 Pt 2

ERRATUM

p. 424, line 30 should read—

> 'fauna of the inland plains of New South Wales has virtually disappeared during the'

CORRIGENDA

p. 494, line 4 of Appendix 1, after 'identifications' insert—

> 'of limb bones; otherwise, throughout the appendix, the identifications'

p. 496, line 8, delete 'one of *Thylacinus*,'

---

described as occurring with, or at the same locality as, *Baragwanathia* by Lang and Cookson (1935) and Harris and Thomas (1937) led him to suggest that these forms may be monograptids of the *M. hercynicus* type. Since that time, he has been engaged in a study of actual specimens of these forms from the 19 Mile Quarry locality on the Yarra Track and other monograptids of this type from that and other localities in Victoria. Jaeger (1962a, b) commented upon his initial examination of some of these specimens and will soon publish the results of his study of collections sent to him.

Papers accepted for publication by the Society during 1964 and edited under the authority of the Council. The authors of the several papers are individually responsible for the accuracy of the statements made and the soundness of the opinions given therein.

DESCRIPTION AND AGE SIGNIFICANCE OF *M. HERCYNICUS* TYPE MONOGRAPTIDS FROM EILDON, VICTORIA

By William B. N. Berry

Museum of Palaeontology, University of California, Berkeley

Abstract

Monograptids of the *M. hercynicus* type have been recovered from the lowest part of the Wilson's Creek Shale and possibly the stratigraphically highest part of the Eildon Group on the slopes of Mt Sugarloaf at Eildon, Victoria. The monograptids found are assignable to two distinct forms, one of which may only be a highly distorted version of the other. The undistorted form is a new species. It was found in beds at the same stratigraphic level with those bearing *Baragwanathia* and also in those bearing hyolithids at a higher stratigraphic level. The same new species is being described by Jaeger from the *Baragwanathia*-bearing beds at the well-known 19 Mile Quarry locality on the Yarra Track.

Monograptids of the *M. hercynicus* type are at present known to occur only in strata of post-Ludlow age. The new species found at Eildon is considered to be indicative of a Gedinne age. Whether the Gedinne Stage belongs in the Silurian or Devonian System is a matter of debate among students of the boundary between these Systems. The author favours a Devonian position for it, and thus the *M. hercynicus* type monograptid-bearing beds at Eildon are considered Early Devonian in age. Further, they are considered correlative with the *Baragwanathia* and *M. hercynicus* type monograptid-bearing beds at the 19 Mile Quarry locality.

Introduction

Although *Monograptus hercynicus* and another monograptid of the same type, *M. kayseri*, were described by Perner in 1899, monograptids of this kind have been little cited in geologic literature until the studies made by Pribyl (1942) and Jaeger (1959). Indeed, Jaeger's work on monograptids of this sort has stimulated a considerable widespread interest in them, particularly from the point of view of their age significance, and they have recently been recognized in a number of parts of the world. Jaeger (1959, p. 84-86) summarized several of the known occurrences to that time and, since then, Jackson and Lenz (1963) have described a new species of the *M. hercynicus* group from the Yukon area in Canada, and Jaeger and the author have recognized monograptids of this group from the central part of Nevada in the United States and from the Gaspe Peninsula in E. Canada. Jaeger has also recognized monograptids of this type in collections from Poland and other areas in central Europe as well.

The possible occurrence of monograptids of this group in Australia was first noted by Jaeger (1959, p. 84-85) when he commented that his examination of figures of *Monograptus uncinatus* var. *orbatus* and *M. uncinatus* var. *micropoma* described as occurring with, or at the same locality as, *Baragwanathia* by Lang and Cookson (1935) and Harris and Thomas (1937) led him to suggest that these forms may be monograptids of the *M. hercynicus* type. Since that time, he has been engaged in a study of actual specimens of these forms from the 19 Mile Quarry locality on the Yarra Track and other monograptids of this type from that and other localities in Victoria. Jaeger (1962a, b) commented upon his initial examination of some of these specimens and will soon publish the results of his study of collections sent to him.

While examining graptolite collections at the National Museum of Victoria, the author came across a small collection of monograptids of the *M. hercynicus* type made by Mr E. D. Gill. The collection was obtained from beds exposed in a trench cut into the bedrock of the southerly slope of Mt Sugarloaf near Eildon, Victoria at the time Dr D. E. Thomas was studying the geology of the Eildon area prior to construction of the present Eildon Dam and reservoir. Anxious to obtain more of these monograptids, the author and Mr Gill made a trip to Eildon in August 1963 and collected a relatively large number of graptolites from the south-western side of Mt Sugarloaf. The recovery of these forms was recorded by the author (1964) in a short note.

Acknowledgements

The author is indebted to Mr E. D. Gill for taking him to the Eildon area and collecting there with him, for turning over for study the collection initially made by him, and for many discussions concerning Victorian Siluro-Devonian stratigraphy. The author thanks Dr John Talent for giving him the pertinent publications on the geology and palaeontology of the Eildon area and for his many helpful discussions and letters concerning the stratigraphic and age problems in that area. The author is also deeply indebted to Dr Hermann Jaeger for examining specimens from Eildon and for considerable help with the determination of them. Both the author and Dr Jaeger have studied the 19 Mile Quarry specimens in some detail but, as Dr Jaeger has been working with and writing about these forms since 1959, he will, in another publication, describe the 19 Mile Quarry specimens and name the new species which occurs both there and at Eildon. In the course of correspondence between Dr Jaeger and the author concerning the identity of the 19 Mile Quarry and Eildon area monograptids, both have agreed that the same new species of monograptid of the *M. hercynicus* type is present in both areas.

Age Significance of M. hercynicus Type Monograptids

Monograptids of the *M. hercynicus* type are among the youngest monograptids known. Perner (1899, p. 11) noted that the two species he described came from the f_1 beds of the Bohemian Lower Palaeozoic succession and that the age of these beds might well be Devonian. Despite that early reference of these kinds of monograptids to beds of possible Devonian age, monograptids have commonly been considered to be restricted in their range to the Silurian, and that the youngest part of the Silurian might be denoted by the last monograptid. Indeed, Jaeger (1959), in his discussion of Thuringian monograptids of the *M. hercynicus* type, indicated the age of the beds from which they came as Latest Silurian. In a subsequent work, however, he (1962a) discussed the correlation of these and other German and the Bohemian strata bearing *M. hercynicus* type monograptids with the typical Ludlow Series (Late Silurian) deposits in Wales and the Gedinne and Siegen Stages. He showed (1962a, p. 127) that *M. hercynicus* may range into beds as young as Siegen age and that other monograptids of the *M. hercynicus* type which occur stratigraphically below *M. hercynicus* in Germany and Bohemia were restricted in their range to beds of post-Ludlow and probable post-Silurian age.

The placing of the Gedinne with the Devonian is open to some debate among students of the Siluro-Devonian boundary and its problems. As discussed by Jaeger (1962a), if the top of the Ludlow be considered the top of the Silurian and the Ludlow be correlated with the $e\beta_1$ beds in the Bohemian succession and the Malinovetzki Beds in Podolia, and if the correlation of the Borszezow Beds in Podolia and the basal part of the Lochkov Limestone (the $e\gamma$ beds) of the Bohemian succession with the Gedinne be accepted, then in both Podolia and Bohemia, fossiliferous beds lay between those correlated with the top of the Ludlow and those with the base of the Gedinne. These are the $e\beta_2$ beds of the Bohemian sequence and the Skala Beds of Podolia. Boucot and Pankiwskyj (1962) designated a new Stage, the Skala Stage, to encompass these beds and that part of the geologic succession lying between rocks correlated with the Ludlow and those correlated with the Gedinne. As Boucot and Pankiwskyj (1962) pointed out, the fauna of the Skala Stage is typified by the presence of a few characteristically Devonian elements such as certain terebratuloid brachiopods and it lacks many diagnostic Silurian elements. It may thus best be included in the Devonian. The fauna of the Skala Stage is considered transitional in character between those of the Ludlow and Gedinne Stages and as such to typify a new time-stratigraphic unit between these two.

Some students of the Siluro-Devonian boundary wish to include all monograptid-bearing rocks in the Silurian. If this is done, then rocks bearing monograptids of the *M. hercynicus* type and shelly fossils that permit correlation with the Skala, Gedinne, and at least lower part of the Siegen Stages, the $e\beta_2$ beds and the Lochkov Limestone in Bohemia, for example, would be placed in the Silurian. The shelly faunas in these beds are Devonian in aspect and permit correlation with Devonian systemic sub-divisions.

If the shelly fossils be relied upon for recognition of the Siluro-Devonian System boundary, as they have been for recognition of the sub-division of these Systems, then the Skala Stage may be considered the basal Stage of the Devonian. If this be done, then the appearance of monograptids of the *M. hercynicus* type may be taken as diagnostic of the lower part of the Devonian. This monograptid group makes its first appearance in beds correlative with the Skala Stage and seems to have been derived from the older, typically Ludlow age *M. uncinatus* group.

The matter of the position of the Skala and Gedinne Stages and their correlatives in the Devonian is thus a subject of some debate among students of the typical areas of the Silurian and Devonian. In this work, the author will follow the suggestions and use of Boucot (oral communications 1962-64) and refer the Gedinne and Skala Stages and their correlatives to the early part of the Devonian.

The *M. hercynicus* type monograptid described by Jackson and Lenz from the Yukon came from strata interbedded with those bearing a brachiopod and coral fauna. The brachiopods in this fauna were studied by Johnson and Boucot who concluded (in Jackson and Lenz 1963, p. 752) that they indicated a 'post-Ludlow and probably early Gedinnian' age. The *M. hercynicus*-bearing beds in central Nevada occur stratigraphically above those bearing a brachiopod fauna concluded by Johnson and Boucot (written communications 1961-62) to be of Early Devonian age. Further, the *M. hercynicus* type monograptids from the Gaspe Peninsula in E. Canada occur above beds bearing a shelly fauna concluded by Boucot to be of Early Devonian age. The monograptids from this area are *M. aequabilis,* which Jaeger (written communications 1963-64) concludes only occurs in Early Gedinne age beds in central Europe. Nikiforova and Obut (1960) listed *M. hercynicus* as occurring in strata in central Asiatic Russia with brachiopods that suggest a possible Gedinne age.

In summary, in all areas in which monograptids of the *M. hercynicus* type have been found with or in close association with shelly fossils, the shelly fossils have been interpreted to be of post-Ludlow and, in the sense of this work, Early Devonian age. Further, monograptids of this type are at present known to be restricted in their range to beds herein considered of Early Devonian age. For these reasons, an occurrence of *M. hercynicus* type monograptids is now concluded by the author to be evidence of an Early Devonian age for the beds bearing them wherever found, until such time as this age span may be increased. Jaeger's (1962) careful study of the European correlations of the graptolite-bearing strata with the Stage and Series of the Devonian and Silurian which are based upon shelly fossils, and the Devonian age interpretation of the shelly fossils that occur with or below *M. hercynicus* type monograptids are considered by the author as reasonably conclusive evidence in favour of this contention.

The Eildon Collections

STRATIGRAPHIC POSITION

The graptolites collected by Mr Gill and the author came from three different stratigraphic levels. The stratigraphically lowest collection was made at the southwestern end of a large quarry face cut into the southerly slope of Mt Sugarloaf which rises above the western side of the Eildon reservoir. A few fragmentary nautiloids and a specimen of *Baragwanathia* were also obtained at the same stratigraphic level. The other collections were made from outcrops on the road southwest of the quarry face. The road trends northeasterly toward a nearby boat harbour. The two stratigraphically higher collections came from the western side of the road in exposures southwest from those in the quarry. The stratigraphically highest collection was obtained in the topographically uppermost part of the road cut. It contained some hyolithids as well as graptolites. The stratigraphically medial collection came from approximately 10 ft beneath the highest. This contained only graptolites, but the largest number of specimens are present in this collection.

The original collection made by Mr Gill from the slopes of Mt Sugarloaf could not be accurately located relative to those made by the author with Mr Gill. The trenches that Dr Thomas had cut to enable his geologic studies of the area appear (from plan No. 14301 in Thomas 1947) to have been cut primarily across the beds depicted on that plan as the Eildon beds. One trench did extend a considerable distance into what is depicted as Plant-Graptolite Beds on that plan. Mr Gill's notes suggested that the collection might have been obtained from the northeastern slope of Mt Sugarloaf. From his discussions with Mr Gill, the author is of the opinion that the original collection came from the steeper slopes of Mt Sugarloaf, from beds depicted in the plans included in Thomas's (1947) report on the geology of the area as Eildon beds. Two graptolite forms were recognized in each of the three collections made by the author with Mr Gill's aid and the same two forms are present in the original collection made by Mr Gill.

The assignment of the strata from which the monograptids collected and studied by the author came to a stratigraphic unit is a matter that is, to some extent, open to differing opinions. Without doubt, the two stratigraphically higher collections obtained by Mr Gill and the author came from those strata designated by Thomas (1947, p. 16) as the Plant-Graptolite Beds. These strata were also termed (Thomas 1947, p. 16 and Plans 14302, 14312, and 14315) the *Uncinatus* Beds and the *Baragwanathia-M. uncinatus* Beds.

The stratigraphically lowest of the three collections made by the author with

Mr Gill also came from the Plant-Graptolite Beds. The author, however, is of the opinion that the graptolite-bearing rocks which fall within the lowest part of the Plant-Graptolite Beds are so folded that they may be traced into the stratigraphically highest strata of that unit designated by Thomas (1947, p. 16) as the Eildon Beds. This opinion was that intended to have been made by the author (1964, p. 223) in his earlier note. This point, however, was not clearly expressed there. In the author's opinion, the lowest part of the sequence shown by Thomas (1947, Plan 14315 'Geological Sections 2-2′ & 3-3′ Through Sugarloaf') as 'Thin bedded Black Mudstones and Sandstones' of the *'Baragwanathia-M. uncinatus* Beds' is the lateral equivalent, now folded, of the uppermost part of the Eildon Beds designated 'Mainly fine grained Sandstones & thin Mudstones' by Dr Thomas (1947, Plan 14315, Geological Sections 2-2′ and 3-3′). The author's opinion is derived from his examination of the exposures in the quarry face on the southerly side of Mt Sugarloaf. These excellent exposures were not available to Dr Thomas in the course of his geological investigation of the area and hence his opinion on this matter could not be expressed at the time he completed his report. Despite the fact that these exposures were not available to him, his mapping and diagrams are interpreted by the author as suggesting the possibility of such folding. Further, despite the lack of such well-exposed outcrop, Dr Thomas's section (1947, Plan 14315, Geological Section 2-2′) drawn approximately through the same position on Mt Sugarloaf that the present quarry face is now located, is remarkably similar in detail to the contorted nature of the beds revealed by this quarry excavation subsequent to his investigation. The author's opinion on the lateral equivalency of the highest part of the Eildon Beds with the lowest part of the Plant-Graptolite or *Baragwanathia-M. uncinatus* Beds is not shared by members of the Geological Survey of Victoria nor by the Geology Department of the University of Melbourne (Talent, written communication 1964).

In the author's opinion, the original collection made by Mr Gill came, with reasonable probability, from the upper, or 'Mainly fine grained Sandstones & thin Mudstones' part of the Eildon Beds as depicted in Geological Section 2-2′ in Plan 14315 by Thomas (1947). Because the author is of this opinion, because he believes that the lowest part of the Plant-Graptolite Beds (*Baragwanathia-M. uncinatus* Beds) are lateral equivalents of the highest part of the Eildon Beds, and because the same graptolites were recovered from these strata as well as from stratigraphically higher strata clearly within the lower portion of the Plant-Graptolite Beds, the stratigraphically highest part of the Eildon Beds is interpreted to be virtually of the same age as the stratigraphically lowest part of the Plant-Graptolite Beds. The strata involved in this age interpretation are only those from which graptolites have been obtained. No implication is intended for any others. The graptolite-bearing rocks are not precisely the same age, for superposition obviously makes the stratigraphically lower ones older than those stratigraphically above. Within the limits of refined age determination permitted by the fossil evidence, however, and with due cognizance of the age differences imposed by superposition, the graptolite-bearing strata are of approximately the same age.

Thomas (1947, p. 16) noted that the Plant-Graptolite Beds and the underlying Eildon Beds, as well as the Upper Sandstone Beds which overlay the Plant-Graptolite Beds, were a part of the 'Jordan River Beds (and Donnellys Creek Beds)'. Later, Thomas (1953, p. 27) published the chart reproduced here as Table 1 which suggests that the Plant-Graptolite Beds had been named the Wilson's Creek Shale and the Eildon Beds, the Eildon Group.

TABLE 1

Taken from Thomas (1953, p. 27) with addition of the column showing age interpretation of graptolite-bearing rocks of this study

Age of graptolite-bearing rocks of this study	Thomas (1953)		—	Thomas 1947	
? ↑ Gedinne — ? —	Jordan River Group	Norton's Creek Sandstone	Tanjilian	Upper Sandstone Group	Tanjilian (in part at least)
		Wilson's Creek Shale	Melbournian	Plant-Graptolite Beds (shown on the plans accompanying Memoir 16 as *Baragwanathia-M. uncinatus* beds)	Melbournian
Skala and older		Eildon Group		Eildon Beds	?Eildonian

Age of the Eildon Collections

PREVIOUS INTERPRETATIONS

The age of the beds from which the graptolites were collected by the author and Mr. Gill at Eildon would appear from the chart (Table 1) to have been correlated with the Melbournian in part in the past. The age of the highest part of the Eildon Group of this chart was left in question. In regard to local Silurian subdivisions and their correlation, Thomas (1960, p. 13) stated that 'four subdivisions of the Silurian are recognized in Victoria and they are correlated with the Silurian of Britain as follows:

	Victoria	Britain
4	Tanjilian	Upper Ludlow
3	Melbournian	Lower Ludlow
2	Eildonian	Wenlock
1	Keilorian	Llandovery'.

Philip (1960) discussed these subdivisions of the Silurian in Victoria and indicated (Fig. 2, p. 146) that although the Keilorian equivalency with the Llandovery or Valentian and that of the Eildonian with the Wenlock had been relatively consistent throughout the use of these terms by various authors, some range of opinion existed concerning the equivalency of the Melbournian and the Tanjilian with the British sequence, and indeed with each other, in part, as well.

The original age assignment of the beds from which the author and Gill's graptolite collections were obtained would appear to have been latest Eildonian (or Wenlock) and earliest Melbournian (or Ludlow) in age from Philip's (1960) and Thomas's (1947, 1960) discussions of the correlation of the local subdivisions of the Silurian in Victoria with the British Series of the Silurian.

The recognition of the Eildonian as a local time subdivision of the Silurian in

Victoria has been discussed by Philip (1960, p. 145) as follows: 'Thomas (1947) recognized a further subdivision of the Silurian of Victoria in the Eildon district in the northern part of the Walhalla Synclinorium. This stage, designated the "Eildonian", occurs stratigraphically above Keilorian beds containing *Monograptus exiguus* and below plant-graptolite beds of Melbournian age. The subdivision then is roughly equivalent to the Wenlockian. No graptolites have been found in Eildon Beds, but a small tabulate coral fauna from a limestone horizon within the unit was determined by Hill (1947) who concluded that the fauna was Upper Ludlow in age'. Philip (1960, p. 149) also pointed out that, in his opinion, Hill's age interpretation of the corals from the Eildon Beds was somewhat younger than he might interpret them. Hill (written communication 1963) indicated that she would still favour the Late Ludlow age interpretation expressed in 1947.

This discussion by Philip and the chart included in Thomas's (1947, p. 16) report on the geology of the Eildon Dam area led the author to indicate (1964, p. 223) that Thomas had designated the Eildon Beds as typical of the Eildonian Stage and to further suggest the possibility that a part of that stage might be correlated with the Early Devonian Gedinne Stage. Talent (written communications 1964) has pointed out to the author that Dr Thomas never specifically designated a type locality or area for the Eildonian Stage. The first mention of the term Eildonian in the category of a Silurian subdivision appears in the work on the Eildon area, and the Eildon Beds are questionably referred to that subdivision, yet a type section or area was not then and has not been definitively denoted. The subdivision is considered to be a correlative of the Wenlock in Britain, and thus the graptolite-bearing beds related to the uppermost part of the Eildon Group by the author must be younger than the age of the Eildonian on the basis of the author's age interpretation of the graptolites.

Some fragmentary graptolites were described by Harris and Thomas (1948) from the Eildon Beds but they do not permit a close, refined age determination for the strata from which they came. Both the author (1964, p. 223) and Philip (1960, p. 145) were in error in stating that no graptolites had been described from the Eildon Beds for Harris and Thomas (1948) did describe and figure a few fragmentary dendroids and one monograptid collected from the Eildon Beds mapped by Thomas (1947, locality 13 on Plan 14303) on the eastern slope of Mt Pinninger. The graptolites collected by the author and Mr Gill are the first specifically identifiable forms to be described and interpreted for their age significance from strata possibly belonging in the Eildon Group exposed on Mt Sugarloaf.

This Study

The graptolites described herein are monograptids of the *M. hercynicus* type. As monograptids of this type have formerly only been found in beds of Early Devonian (or at least post-Ludlow) age, the rocks from which the collections made by Mr Gill and the author came are considered to be post-Ludlow and Early Devonian in age. Jaeger (written communication 1964) has stated that he identified a species of the *M. hercynicus* type known to occur only in Early Gedinne age beds in a collection sent to him by Talent. The collection bearing this species was reported to have come from about 3500 ft below the 19 Mile Quarry beds that bear *Baragwanathia* and the same new species of monograptid of the *M. hercynicus* type as that found by the author in his and Mr Gill's collections from the basal part of the Wilson's Creek Shale and possibly the uppermost part of the Eildon Group at Eildon. The rocks bearing the new species of monograptid of the *M. her-*

cynicus type thus appear to be of Gedinne and probably Late Gedinne or possibly even younger age, in the opinion of both Jaeger and the author.

On the basis of this evidence, the author concludes that the lower part of the Wilson's Creek Shale and possibly the highest part of the Eildon Group exposed on Mt Sugarloaf, those beds and only those beds from which graptolites were obtained, are of Gedinne and possibly Late Gedinne or younger age. The fossil evidence suggests that the beds from which the graptolites were collected on the slopes of Mt Sugarloaf may be correlated with at least those beds bearing *Baragwanathia* and the new species of *Monograptus* of the *M. hercynicus* type at the 19 Mile Quarry locality.

If the correlation of the local Silurian subdivisions in Victoria noted by Thomas (1960, p. 13) and Philip (1960, p. 146, Fig. 2) be followed and the Melbournian, at least in part, is correlative with the Early Ludlow and the Tanjilian with the Late Ludlow, then the basal part of the Wilson's Creek Shale and possibly the highest part of the Eildon Group on the southwestern slopes of Mt Sugarloaf must be younger than either the Melbournian or the Tanjilian. If the Yeringian at least in some part, is correlative with the Gedinne, then, in terms of the local systemic subdivisions in Victoria, the basal part of the Wilson's Creek Shale and the stratigraphically highest part of the Eildon Group on the slopes of Mt Sugarloaf are correlative with that part of the Yeringian that may be correlated with the Gedinne. Further, Philip (1960, p. 155) noted the monograptids Jaeger (1959) considered to be of the *M. hercynicus* type occur associated with *Baragwanathia* 'at the base of the Tanjil Beds and their equivalents'. If the *Baragwanathia* and monograptid-bearing part of the Tanjil Beds occurs within the Tanjilian, then that part of the Tanjilian is a correlative of the Gedinne. If that be the case, then at least a part of the Tanjilian may be correlated with a part of the Yeringian.

Systematic Descriptions

Two forms of monograptids of the *M. hercynicus* type are present in collections made by Mr Gill and the author from the slopes of Mt Sugarloaf. One form is relatively long and slender compared to the other. Most of the slender forms lie in one direction which appears to be that of maximum movement during deformation of the rocks in which they are entombed. The slender forms in general lie parallel to each other and at right angles or a high angle to the wider, shorter forms.

As Jaeger (1959, p. 69-77) has discussed, many monograptids may be so severely deformed during deformation of the rocks in which they are entombed that length and width may be markedly changed from their original state and even thecal number and characteristics changed noticeably. Indeed, Jaeger (1959, p. 73) noted among rhabdosomes of the same species of monograptid that those rhabdosomes lying parallel to the axis of greatest movement had a thickness of about 2 mm and 12 thecae in 10 mm, whereas those rhabdosomes that lay at right angles to this axis had a thickness of about 3 mm and 16 thecae in 10 mm.

All the rhabdosomes encountered in the present study may well belong to the same species, with the longer ones having been subject to strong deformation, whereas the shorter and wider ones have been preserved with more nearly their original dimensions. Jaeger (written communication 1964) is of the opinion that both of these forms belong to the same species.

The wider forms lie at many angles to the slender forms, but never parallel to them. A few do lie at an 8 to 10 degree angle to the slender forms. The dimensions of each form are such that each falls within a group of specimens distinct from the other. Even among those wider specimens lying at low angles to the slender ones, no evidence of intergradation between the two groups was observed. For this reason, the two forms may be phyletically distinct. For the present, however, they will be described as two different forms of the same species with the realization that they may be two distinct species or that they may be perhaps more probably, merely two differently preserved forms of the same species. The shorter, wider, and less deformed form is designated Forma A, and the slender, elongated form is designated Forma B.

Class GRAPTOLITHINA Bronn 1846
Order GRAPTOLOIDEA Lapworth 1875
Suborder MONOGRAPTINA Lapworth 1880
Family MONOGRAPTIDAE Lapworth 1873
Genus **Monograptus** Geinitz 1852

The writer follows the suggestion made by Bulman (1963, p. 416) in retaining the broad generic grade *Monograptus* as a general portmanteau in descriptive studies of graptoloids with uniserial scandent rhabdosomes until such time as phylogenies and lineages within the grade may be established.

Monograptus sp. nov. (of the *M. hercynicus* type) FORMA A

(Pl. 1, fig. 1-11; Pl. 2, fig. 7-9, 11; Fig. 1a, b)

MATERIAL: 8 complete and 45 fragmentary rhabdosomes. Some of the rhabdosomes are preserved in low relief whereas others are highly compressed and crushed.

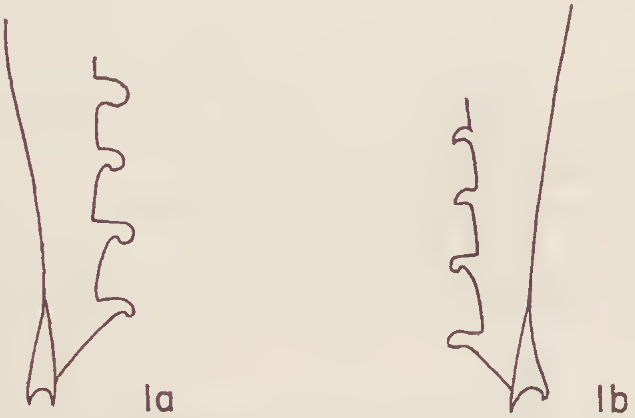


FIG. 1a, b—Proximal ends of *Monograptus* sp. nov. (of the *M. hercynicus* type) Forma A (×10) showing the isolate nature of the apertural hooks or hoods of the proximal thecae and Th 1 in particular and the detail of the sicula aperture with its ventral spine and dorsal projection. These proximal end features are diagnostic ones of this new species. Nat. Mus. of Vict. Reg. No. P23100.

DIAGNOSIS: Rhabdosome commonly has broad, gentle S-shape with dorsal curvature in proximal 1·5-2·0 mm, then bending to ventral curvature in the next 4-8 mm, then bending gently back to broad dorsal curvature in most; 13-23 mm long; 0·9-1·1 mm wide at first thecal aperture (measured with thecal hood) and width increases to maximum of 1·8-2·1 mm (with thecal hood); thecae of *uncinatus* type (as described by Jaeger 1959, p. 86), more strongly hooked in proximal portion than in distal, 10-12 in 10 mm; sicula narrow in upper part but widens markedly in lower part, 1·5-1·8 mm long and 0·5-0·6 mm wide at aperture.

DESCRIPTION: Most of the rhabdosomes of this species have a broad S-shape. The proximal 1·5-2·0 mm is bent dorsally, then the rhabdosome curves sharply to the ventral side and the next 1-3 mm is marked by a pronounced ventral curvature. The ventral curvature becomes less pronounced farther away from the proximal end, but the next 4-8 mm of each rhabdosome taken distally from the proximal dorsal curvature is curved ventrally. Distally from the ventral curvature, most rhabdosomes have a broad, gentle dorsal curvature which encompasses the remainder of the length of the rhabdosome. Some rhabdosomes become straight in the distal part and are not curved, and two had a slight dorsal curvature followed by a slight ventral curvature in their distal portions. In general, however, the gentle S-shape characterizes most rhabdosomes.

The rhabdosomes are relatively short, a few complete ones measuring but 12-13 mm in length. Most of the complete rhabdosomes have lengths of 15-23 mm. The longest of the rhabdosome fragments are 19-21 mm long and are very nearly complete, thus suggesting that rhabdosome length did not exceed 25 mm at most.

The rhabdosomes are 0·9-1·1 mm wide at the first theca, the width including the thecal hook or hood. The width at the first theca without the hook or hood is 0·6-0·7 mm. The rhabdosomes widen to 1·0-1·3 mm without the thecal hook and 1·3-1·6 mm with the thecal hook or hood at 5 mm from the sicula aperture and to 1·4-1·8 mm without the thecal hook or hood and 1·6-2·1 mm with the thecal hook or hood at 10 mm from the sicula aperture. At 15 mm from the sicula aperture, the rhabdosomes are 1·4-1·8 mm wide without the thecal hook or hood and 1·7-2·0 mm wide with the thecal hook or hood. The widths attained at 15 mm are maintained throughout the remainder of the rhabdosome. The greater widths are seen in the more compressed specimens and, in some of them, the width may be slightly (0·1 mm) greater at a given distance than the range indicated. The lesser widths cited are those of specimens preserved in low relief.

The thecae are of the *uncinatus* type. The proximal 7-12 thecae are more strongly hooked than are the distal thecae. The hooks or hoods (hauben in the sense of Jaeger 1959, p. 79) are pronounced on the proximal thecae but they are but small, slender tubes that are but weakly hooked in the distal portions of the rhabdosomes. The hooks in the initial two thecae appear to project out from the ventral wall very prominently, making these thecal hooks more isolate from the rhabdosome than any others.

The thecae number 5½-6½ in the initial 5 mm and 10½-12½ in the initial 10 mm. They number 10-12 in distal portions of the rhabdosome.

The strongly hooked thecae in the proximal region, at a distance greater than 4 mm from the sicula aperture, are 1·8-2·2 mm long and they are free 0·7-0·8 mm. They are 0·6-0·8 mm wide measured vertically between the near-horizontal portions of the interthecal septa. The hooked part of the thecae is 0·2-0·3 mm wide and the hood or free hook is 0·4-0·5 mm high. The height of the hood is measured as the vertical distance from the level of the thecal aperture to that of the point of maximum curvature. The interthecal septum of these thecae has a sloping portion that is 0·6-0·8 mm long and commonly makes an angle of approximately 30° with the rhabdosome axis and a more nearly horizontal portion that is 0·4-0·6 mm long and is at a 20-32° angle with the horizontal. The angle between the two parts of the interthecal septum is 145-155°.

The thecae in the distal portions of the rhabdosome are characterized by having but very small hooks. These thecae are 1·9-2·1 mm long measured diagonally from the aperture to the innermost part of the interthecal septum. They overlap almost their entire length with only the hooked part being free. The free ventral wall of these thecae is straight, 0·6-0·8 mm long, and it makes an angle of 10-20° with the vertical. The thecal hooks project horizontally from the ventral side of the rhabdosome and they are 0·2-0·4 mm long and but 0·1-0·15 mm wide. The interthecal septum has an S-shape. Its ventral part is horizontal and is 0·3-0·4 mm long. This part bends to a sloping portion that is 0·4-0·5 mm long and makes an angle of 15-25° with the rhabdosome axis. The inner or dorsal part is 0·3-0·4 mm long and makes a 20-30° angle with the horizontal.

The sicula is 1·5-1·8 mm long and is 0·25-0·35 mm wide at its aperture. In specimens in which the proximal end has apparently been distorted, the upper 0·8-1·0 mm of the sicula is a narrow cone, but the lower part of the sicula widens and has a relatively broad, open conical shape. Such siculae are 0·5-0·6 mm wide at their apertures, and they have a general resemblance to siculae of *M. hercynicus*.

The sicula aperture has a relatively broad projection on the dorsal side which is 0·5-0·7 mm long. A slender spine 0·2-0·4 mm long extends from the ventral side of the sicula aperture.

REMARKS: These forms resemble *M. praehercynicus* but, in general, are shorter and somewhat more curved in rhabdosome shape than that species. The thecal hooks or hoods of the first two thecae are more prominent and isolate in this form than in *M. praehercynicus*, and the sicula in this form has a dorsal projection which siculae of *M. praehercynicus* do not have. Further, the number of thecae in 10 mm may be slightly greater in this form than in *M. praehercynicus*.

Specimens identical with these have been recognized by the author in collections from beds bearing *Baragwanathia* from 19 Mile Quarry. This opinion has been corroborated by Jaeger's (written communication 1964) work on the 19 Mile Quarry specimens and his examination of a small collection from the Eildon area.

Monograptus sp. nov. (of the *M. hercynicus* type) FORMA B

(Pl. 2, fig. 1-6, 10, 11)

MATERIAL: 5 complete and 26 fragmentary rhabdosomes. Some of the rhabdosomes are preserved in low relief whereas others are highly compressed and crushed.

DIAGNOSIS: Rhabdosome with dorsal curvature in proximal 1·5-2 mm, bending to ventral curvature for next 5-9 mm and then straight thereafter; 22-32 mm long commonly and one specimen is 41 mm; widens from 0·9-1·1 mm at first thecae (measured with thecal hood) to a maximum of 1·1-1·2 mm; thecae of *uncinatus* type, more strongly hooked in proximal portion than in distal, 8-9 in 10 mm; sicula narrow and conical, 1·8 mm long and 0·3 mm wide at aperture.

DESCRIPTION: 4 of the 5 complete rhabdosomes have lengths in the span of 22-32 mm and the fifth is 41 mm long. The proximal 1·5-2·0 mm of the rhabdosome is bent slightly to the dorsal side. This slight dorsal curvature takes place in the distance of the length of the sicula. A bending toward the ventral side takes place either at or within 0·3-0·5 mm of the sicula apex. The ventral curvature of the rhabdosome encompasses the next 5-9 mm of the rhabdosome length. It is more pronounced in the proximal 2-3 mm of its expression and becomes gradually less pronounced. Those portions of the rhabdosome distal from the ventral curvature are straight and the distal portions of the rhabdosome are characterized by their straight and almost parallel-sided appearance.

The rhabdosomes are 0·9-1·0 mm wide at the first thecal aperture. This width is measured with the width of the hooked portion of the theca included. The width at the first theca without this portion included is 0·5-0·75 mm. The rhabdosome width at 5 mm from the sicula aperture is 1·0-1·2 mm with the width of the hooked portion of the nearest theca included and 0·5-0·95 mm without this part of the theca included. The width at 10 mm from the sicula aperture is 1·1-1·3 mm with the hooked part of the nearest theca included and 0·9-1·1 mm without that part of the theca. The rhabdosome width at 15 mm from the sicula aperture is 1·0-1·2 mm with the hooked part of the nearest theca included and 0·9-1·1 mm without that part of the theca. The widths at distances of 20, 25, 30, and 35 mm from the sicula aperture fall within the same span as those at 15 mm. The rhabdosome width without the hooked part of the theca thus is constant from 10 mm from the sicula aperture throughout the remainder of the length of the rhabdosome in most of the specimens studied. In a few, this width is attained at 6-7 mm from the sicula aperture and remains the same throughout the remainder of the rhabdosome.

The thecae, in general, are of the *uncinatus* type. The proximal 8-12 thecae have strongly developed hooks (hauben in the sense of Jaeger 1959, p. 79) and the prominence of the hooks diminishes markedly beyond these proximal thecae so that the distal ones have but weakly developed hooks.

The thecae commonly number 7¾-8½ in the initial 10 mm, but a few specimens have 9 and a few others have 10 thecae in the same part of the rhabdosome. At distances greater than 15 mm from the sicula aperture, the thecae number 8-9 in 10 mm.

The thecae in the span of 4-10 mm from the sicula aperture are 2·3-2·5 mm long, and 0·4-0·5 mm wide, and they overlap 0·9-1·1 mm. The thecae are essentially tubular in aspect. Where they become free at the ventral margin of the rhabdosome they immediately curve into an open inverted U-shaped form. The thecal aperture appears to be essentially horizontal. The perpendicular distance from the aperture to the level of the base of the U-shape or point of maximum curvature is 0·4-0·6 mm. The thecal aperture is 0·2-0·3 mm in diameter or in maximum dimension, and the curved part of the thecae is 0·2-0·25 mm wide. The hooked part of the thecae in this part of the rhabdosome extends 0·2-0·4 mm from the ventral rhabdosome wall in most thecae and may extend as much as 0·7 mm in a few thecae. Such thecae appear to have been more highly deformed and compressed than the others. The medial part of the interthecal septum in this part of the rhabdosome is straight, 0·4-0·55 mm long, and is oriented at a 17-22° angle to the rhabdosome axis. Its dorsal portion turns to within 8-20° of horizontal and that part is 0·1-0·2 mm long.

The distal thecae, those beyond 15 mm from the sicula aperture, have much less pronounced hooks or hauben, and the hooked part of the thecae is commonly closely pressed to the ventral part of the rhabdosome. The thecae are 2·5-2·8 mm long and 0·3-0·4 mm wide. (The length is measured diagonally from the top of the hook to the base of the theca.) The thecae overlap 2·3-2·5 mm. The hooked part of the thecae projects but 0·1-0·2 mm from the ventral rhabdosome wall and the greater amount of projection is seen in the more highly compressed specimens. The hooked part has the general form of an inverted U and is 0·2-0·28 mm in height measured perpendicularly from the level of the aperture to that of the point of maximum curvature. The thecal aperture is 0·1-0·15 mm in width. The straight medial part of the interthecal septum is 0·7-0·9 mm long, and is inclined to the axis of the rhabdosome at a 8-15° angle. The dorsal part of the interthecal septum turns to become within 5° of horizontal and is 0·1-0·3 mm long.

The sicula has a slender, conical form. It is 1·6-1·9 mm long and is 0·2-0·3 mm wide at its aperture. The first theca appears to have originated about 0·2 mm above the aperture of the sicula and to have grown upward.

REMARKS:The slender and essentially parallel-sided appearance of medial and distal portions of rhabdosomes of this form set it apart from the others in the collections. The manner in which thecae in the distal parts of some rhabdosomes are compressed next to the ventral rhabdosome margin, thus making them appear relatively insignificant, led the author to mention (1964) that these forms were of the *M. microdon* type. Further study of all the specimens obtained from the Eildon area has shown that such forms are merely distorted fragments of this new species. The thecal characteristics of entire rhabdosomes indicate that this is a new form belonging to the *Monograptus hercynicus* group.

References Cited

BERRY, W. B. N., 1964. Siluro-Devonian graptolites from Eildon, Victoria. *Aust. Jour. Sci.*, 26: 223-224.

BOUCOT, A. J., and PANKIWSKYJ, K., 1962. Landoverian to Gedinnian Stratigraphy of Podolia and adjacent Moldavia. *Symposiums-Band der 2nd Internat. Arbeitstagung über die Silur/Devon-Grenze und die Stratigraphie von Silur und Devon*: 1-11.

BULMAN, O. M. B., 1963. The evolution and classification of the graptoloidea. *Geol. Soc. London Quart. Jour.* 119: 401-418.

HARRIS, W. J., and THOMAS, D. E., 1937. Victorian graptolites (new series) Part IV. *Min. and Geol. Jour. Vict.* 1: 69-79.

———, ———, 1948. Victorian graptolites (new series) Part XI. ibid. 3: 43-45.

JACKSON, D. E., and LENZ, A. C., 1963. A new species of *Monograptus* from the Road River Formation, Yukon. *Palaeontology* 6: 751-753.

JAEGER, H., 1959. Graptolithen und Stratigraphie des Jüngsten Thüringer Silurs. *Abhandl. der Deutschen Akad. der Wissenschaften zu Berlin, Klasse für Chemie, Geologie und Biologie* Jahrgang 1959, Nr. 2, 197 p., 14 pl.

———, 1962a. Das Silur (Gotlandium) in Thüringen und am Ostrand des Rheinischen Schiefergebirges (Kellerwald, Marburg, Giessen). *Symposium-Band der 2nd Internat. Arbeitstagung über die Silur/Devon-Grenze und die Stratigraphic von Silur und Devon*: 108-135.

———, 1962b. Das Alter der ältesten bekannten Landpflanzen (*Baragwanthia*-Flora) in Australien auf Grund der begleitenden Graptolithen. *Palaeontologische Zeitschrift* 36: 7.

LANG, W. H., and COOKSON, I. C., 1935. On a flora, including vascular land plants, associated with *Monograptus*, in rocks of Silurian age from Victoria, Australia *Philos. Trans. Roy. Soc. London* Section B 224: 421-449.

NIKIFOROVA, O., and OBUT, A., 1960. Stratigraphy and Palaeogeography of the Silurian deposits in the USSR. *State Scientific-Technical Publishing House, Oil and Mining Industry Literature, Leningrad*: 22-32.

PERNER, J., 1899. *Etudes sur les Graptolites de Bohême, IIIieme Partie.* Monographie des Graptolites de L'Etage E: Prague, Raimund Gerhard.

PHILIP, G. M., 1960. Victorian Siluro-Devonian faunas and correlations. *XXI Internat. Geol. Congress, Part VII*: 143-157.

PRIBYL, A., 1942. Einige kritische Bemerkungen zur Art *Monograptus hercynicus* Perner. *Vest. Kral. Ceske Spol. Nauk. tr. Mat. Pritod.* 7 p., 1 pl.

THOMAS, D. E., 1947. The geology of the Eildon Dam Project. *Mem Geol. Surv. Vict.* 16, 57 p.

————, 1953. Tanjilian fossils. *Min. and Geol. Jour. Vict.* 5: 27.

————, 1960. The zonal distribution of Australian graptolites: *Jour. and Proc. Roy. Soc. N.S.W.* 94: 1-58.

Explanation of Plates

The photographs have not been retouched. They were taken at the Scientific Photographic Laboratory of the University of California, Berkeley, with the exception of Pl. 2, fig. 8 & 9 which were taken by Mr Frank Guy. All figured specimens are deposited in the National Museum of Victoria. The number given each is its catalogue number in that Museum. The collection designation 'lower,' 'medial,' or 'upper' refers to the stratigraphic level of the collection of which the figured specimen is a part made by the author and Mr Gill. Specimens collected by Mr Gill at an earlier time are designated 'Mr Gill's collection'.

PLATE 1

Monograptus sp. nov. (of the *M. hercynicus* type) Forma A

Fig. 1—× 5. P23098. Distal part of rhabdosome; medial collection.

Fig. 2—× 5. P23099. Complete rhabdosome; lower collection.

Fig. 3—× 10. P23100. Proximal end showing sicula, isolate nature of Th 1, and proximal thecae; lower collection.

Fig. 4—× 5. P23101. Portion of the lower and medial parts of a rhabdosome showing apertural hooks; upper collection.

Fig. 5—× 10. P23100. Distal end of rhabdosome showing thecae; lower collection.

Fig. 6—× 10. P23100. Nearly complete rhabdosome; lower collection.

Fig. 7, 8—× 10. P23102. Proximal end of the same rhabdosome. Fig. 7 taken with filter shows outline of proximal thecae and their hooks. Fig. 8 taken without filter shows nature of interthecal septa of the same thecae. Medial collection.

Fig. 9—× 10. P23100. Proximal portion of rhabdosome; lower collection.

Fig. 10—× 10. P23103. Medial and distal portion of a rhabdosome; Mr Gill's collection.

Fig. 11—× 5. P23104. Medial and distal portions of a rhabdosome; upper collection.

PLATE 2

Monograptus sp. nov. (of the *M. hercynicus* type) Forma B

Fig. 1—× 5. P22764. Two complete and a part of a third rhabdosome. The distal thecae and interthecal septa may be most clearly seen. Mr Gill's collection.

Fig. 2, 3—× 10. P23105. Proximal portions of the same rhabdosome. Fig. 2 taken without filter shows nature of interthecal septa. Fig. 3 taken with filter shows thecal hooks of the proximal thecae. These may be contrasted with the characteristics of the distal thecae as seen in Fig. 1, 4, 5, and 6. Mr. Gill's collection.

Fig. 4—× 10. P23105. Distal portion of rhabdosome; Mr Gill's collection.

Fig. 5, 6—× 10. P23105. Distal portion of the same rhabdosome. Fig. 5 taken without filter shows nature of apertural hooks. Fig. 6 taken with filter shows nature of interthecal septa of the distal thecae as well as thecal form. Mr Gill's collection.

Fig. 10—× 10. P23106. Proximal portion of rhabdosome preserved in only a partially crushed form. The tubular nature of the thecal hooks may be seen. Medial collection.

Monograptus sp. nov. (of the *M. hercynicus* type) Forma A

Fig. 7—× 5. P23099. Nearly complete rhabdosome; lower collection.

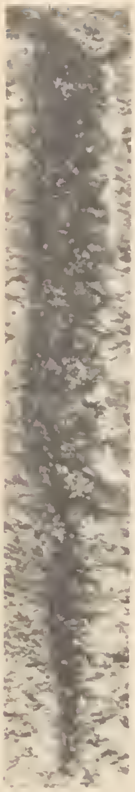
Fig. 8—× 4. P22770. Complete rhabdosome from 19 Mile Quarry locality included here for comparison.

Fig. 9—× 4. P22768. Nearly complete rhabdosome from 19 Mile Quarry locality.

Monograptus sp. nov. (of the *M. hercynicus* type) Forma A and Forma B

Fig. 11—× 5. P23107. Forma A is the horizontal specimen and Forma B is the more nearly vertical specimen. This illustrates the most common orientation between these two Forma seen in the collections.

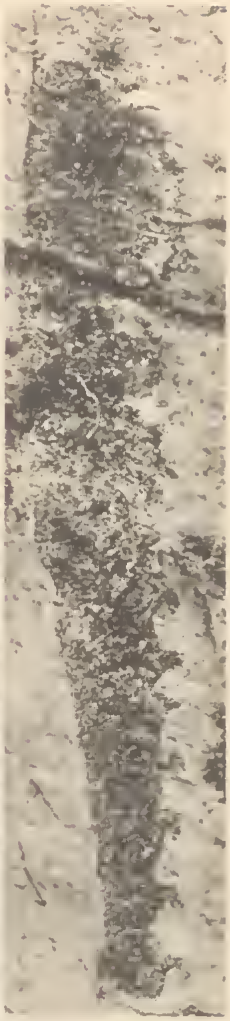

1


2

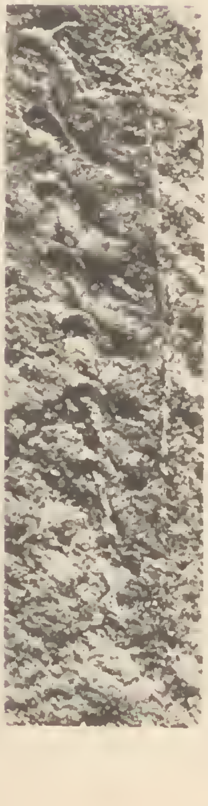

3


4


5


6


7


8

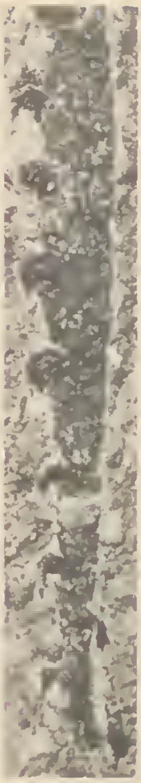

9


10


11

1

2



3

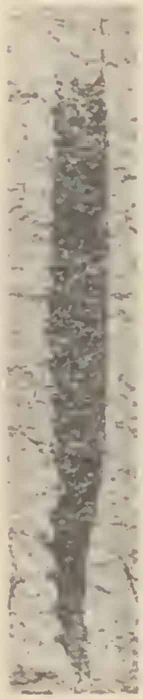
4

5

6

7

8



9

10

11

2

QUATERNARY MOLLUSCA FROM PORT FAIRY, VICTORIA, AUSTRALIA, AND THEIR PALAEOECOLOGIC IMPLICATIONS

By JAMES W. VALENTINE

Department of Geology, University of California, Davis

Abstract

Calcareous marine Quaternary sediments from Port Fairy, Victoria have yielded over 300 species of molluscs in two assemblages. One represents a back-beach deposit assembled from a moderately exposed rocky shore with minor admixtures of shells from other near-shore environments. The other is interpreted as a shallow-water offshore sandy bottom deposit that includes shells from rocky and sandy shores, rocky, sandy and silty shallow offshore bottoms, and rarely, moderately deep offshore bottoms. A rich flora of algae and cryptogams is suggested by the molluscs.

The assemblages include a few species that live today only to the north, and several that live only to the east. The extra-limital forms are interpreted as indicating slightly warmer (1-2°C) summer temperatures than at present; perhaps the cool northward-flowing currents along W. Tasmania were formerly modified.

Introduction

Richly fossiliferous Quaternary sediments are exposed in the Borough of Port Fairy, W. Victoria. The fossils are chiefly molluscs, though Foraminifera are also abundant, and they provide what must be a fairly large sample of the former molluscan associations of the region. The purpose of this study is to record the fossil molluscan associations from two localities, to infer the former environments from which the fossils were assembled, and to assess the biogeographic significance of the fauna.

Attention has been drawn to the Port Fairy Quaternary by Gill (Gill & Fairbridge 1953; 1954), who noted the presence in these deposits of extra-limital molluscs, *Anadara trapezia* and *Ninella torquata,* interpreted as indicating warmer waters than are present today in the Port Fairy region. Radiocarbon analysis of opercula of *Ninella torquata* from one of the localities (Bank St) yielded an age estimate of 'older than 35,000 years' (Gill 1956).

Foraminifera from the Port Fairy Quaternary have been described by Collins (1953), who noted that the associations resemble recent beach and lagoonal associations in the Port Fairy region but contain a few forms that are not known to live near Port Fairy today. These have been interpreted as indicating warmer waters than at present (Collins in Jennings 1959, app. III).

Acknowledgements

Study of the Port Fairy Mollusca was suggested by E. D. Gill, National Museum of Victoria, who accompanied me in the field to many Quaternary localities and provided much data and encouragement, and to whom I am much indebted for these and numerous other courtesies. It is also a pleasure to acknowledge the aid of J. Hope Macpherson, National Museum of Victoria, who drew on her large knowledge of marine molluscs to solve many problems arising during the course of the work.

The late C. J. Gabriel aided in the identification of many of the minute forms, and Robert Burn provided identifications and ecologic data on pleurobranchids and berthelinids. Eric Wilkinson, Patricia Hoggart, and Joyce Shaw, National Museum of Victoria, and Bob Mallory, University of Missouri, aided with various phases of the work. Photographs were made by Frank Guy, Royal Melbourne Institute of Technology. The South Australian Museum, Adelaide, kindly permitted access to their molluscan collections.

Special thanks are due the Sub Aqua Group of Victoria, particularly the Geology Group and Mrs Jeannette Watson, for sampling recent offshore thanatocoenoses and for introducing me to the subtidal benthos of Victoria in its own milieu.

This study was made possible by a Fulbright post-doctoral research fellowship to Australia in 1962-63, and through the generosity of the National Museum of Victoria, Melbourne, on which the work was based. Grants to help defray expense of illustration were provided by the Research Council, University of Missouri, and the University of California, Davis.

FIG. 1—General tectonic setting of W. Victoria and SE. South Australia during the Cainozoic. Partly after Wilkins 1962.

Geological Setting

The general tectonic setting of the Port Fairy district during the Cainozoic is depicted in Fig. 1. Port Fairy lies within the Otway Basin (Bureau of Mineral Resources 1960), bounded to the E. by Mesozoic rocks of the Otway Ra. and to the N. by a persistent Cainozoic high, the Dundas Peninsula. To the W., where magnetic and bore data are available, several tectonic elements have been identified: the Gambier sunklands (Sprigg 1952) in the far W. of the Otway Basin, bounded to eastward by the Dartmoor Ridge (Boutakoff 1952), a tectonic swell running

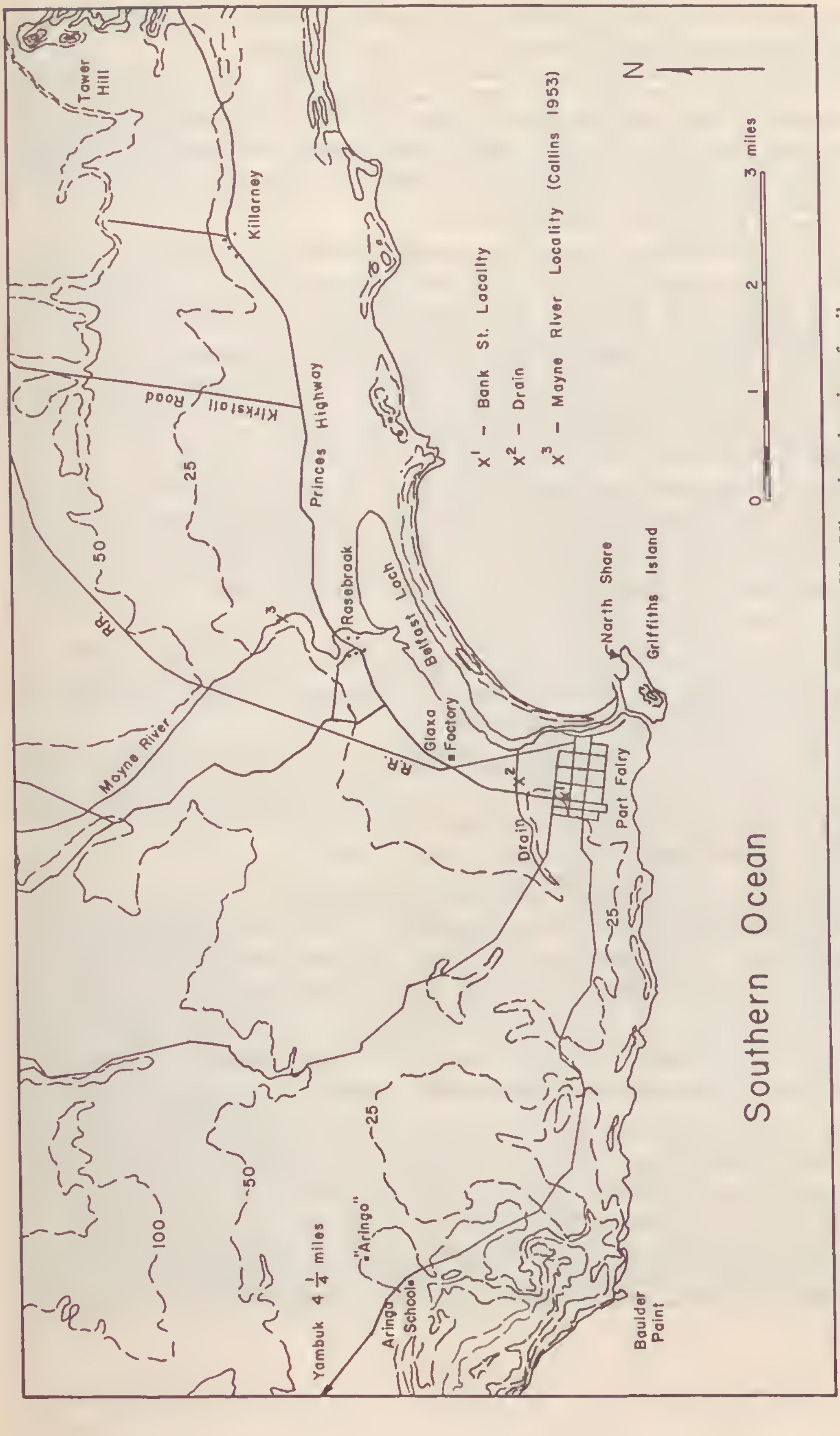


FIG. 2—Sketch map of Port Fairy and vicinity, W. Victoria, showing fossil localities and landmarks mentioned in text. Base map, Australia 1:63,360, Port Fairy sheet.

southward from the Dundas Peninsula from near Casterton to Cape Bridgewater; and the Portland sunklands (Boutakoff 1952) E. of the Ridge.

The oldest rocks outcropping or penetrated by shallow bores in the Port Fairy region are Miocene limestones and marls, evidently continuous with the upper formations of the Heytesbury Group described in the Port Campbell and Moonlight Head districts (Baker 1944, 1950, 1953). This group has not been completely penetrated by bores in the Port Fairy district for which data are available. However, a bore at the Glaxo factory (Chapman 1925, Fig. 2) proved Miocene marls at depths between 94 and 954 ft below sea level.

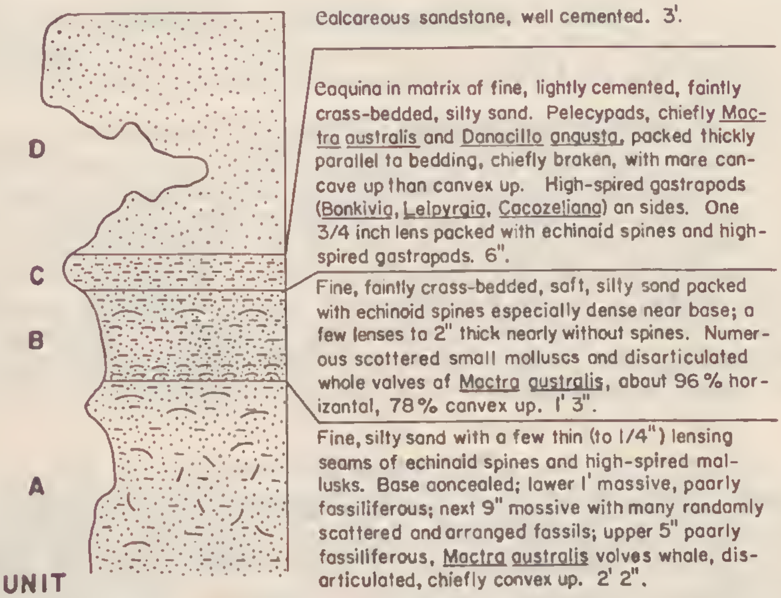
Overlying the Miocene sediments is a basalt assigned to the Newer Volcanics, probably of Pliocene age. Field and bore data collected by E. D. Gill demonstrate the general geometry of the basalt, which has played an important role in the distribution of marine communities along the Pleistocene shores of Port Fairy. I am indebted to Mr Gill for permission to use this unpublished information. The upper surface of the Heytesbury Group had been eroded into a topography of moderate relief before extrusion of the basalt, which occupies a channel in the Heytesbury Group that extends 94 ft below sea level (or thereabouts; Chapman 1925 does not specifically identify the top of the Miocene rocks) in the Glaxo bore (Fig. 2). The Port Campbell Limestone, the upper formation of the Heytesbury Group, outcrops to the W. of Port Fairy near Aringa and Yambuk, and to the E. near Tower Hill, but is evidently absent in the Glaxo bore, having presumably been eroded from the channel. Bores which have bottomed in volcanics have been drilled near the railway station, Port Fairy (basalt to at least 72 ft below sea level) and S. of Rosebrook (basalt to at least 80 ft below sea level).

To the E. of Port Fairy the volcanics outcrop in a drain which crosses the Princes Highway about ⅞ mile W. of its intersection with Kirkstall Rd. Bores less than a mile E. of Killarney, however, failed to penetrate basalt but found sand at depths between 15 and 65 ft below sea level.

Thus the volcanics form a tongue running southward from the W. Victorian Basalt Plains proper along a channel cut in Miocene rocks. The tongue is thickest between Port Fairy and Rosebrook and thins both eastward and westward. The upper surface of the volcanics may itself be deeply channelled in the E. near Killarney, for the lateral change from basalt to sand is abrupt.

In Port Fairy proper the upper surface of the tongue of Newer Volcanics is rather irregular, and variations in its elevation have exercised some control upon the character of the shore line and the distribution of near-shore environments. A break in elevation which follows a N.-S. trend runs along the E. side of Griffith's Is. and separates a region of generally high surface elevations to the W. from one of lower elevations to the E. The coast from Griffith's Is. W. to Boulder Point forms a headland; at the island are rocky shores and offshore rocky bottoms. To the E. the basalt surface is generally well below sea level near the present shore, and the coast is embayed. Information from shallow bores and trenches between Princes Highway and the shore demonstrates a relief of from 21 ft above sea level on an uneven basalt ridge that runs E.-W. along Bank and Regent Streets, to 9 ft below sea level in depressions S. of the ridge. N. of the ridge the basalt surface drops off to unknown depths beneath a thicker blanket of sediments. This drop-off may well represent the margin of an old course of the Moyne R. which ran E.-W. near the coast.

Overlapping the Miocene sediments and Newer Volcanics is a complex of calcareous dune sands with associated marine sands and conglomerates of Quaternary age. Near Portland and in the Mt Gambier sunklands similar sedimentary complexes are mapped as a single unit, the Bridgewater Formation (Sprigg & Boutakoff 1953). The present report is concerned with fossils contained in marine and beach sediments of this complex which veneer the Newer Volcanics E. of the Princes Highway at Port Fairy. To facilitate discussion these fossiliferous sediments are hereafter called the Port Fairy beds, a term used as a sort of nomina aperta outside the formalities of stratigraphic nomenclature. Detailed mapping is required to define useful, mappable formations within the Quaternary complex.



Calcareous sandstone, well cemented. 3'.

Coquina in matrix of fine, lightly cemented, faintly cross-bedded, silty sand. Pelecypods, chiefly *Mactra australis* and *Donacilla angusta*, packed thickly parallel to bedding, chiefly broken, with more concave up than convex up. High-spired gastropods (*Bankivia*, *Lelpyrgia*, *Cacozeliana*) on sides. One 3/4 inch lens packed with echinoid spines and high-spired gastropods. 6".

Fine, faintly cross-bedded, soft, silty sand packed with echinoid spines especially dense near base; a few lenses to 2" thick nearly without spines. Numerous scattered small molluscs and disarticulated whole valves of *Mactra australis*, about 96 % horizontal, 78 % convex up. 1' 3".

Fine, silty sand with a few thin (to 1/4") lensing seams of echinoid spines and high-spired mollusks. Base concealed; lower 1' massive, poorly fossiliferous; next 9" massive with many randomly scattered and arranged fossils; upper 5" poorly fossiliferous, *Mactra australis* valves whole, disarticulated, chiefly convex up. 2' 2".

FIG. 3—Pleistocene sediments exposed at Fig. 2, locality 2, in drain 196 ft E. of Princes Highway.

Stratigraphy of the Port Fairy Beds

On the SE. corner of Bank St and Albert St (Princes Highway), Port Fairy, a 2½ ft-thick conglomerate is exposed in the street cutting. It consists of irregular basalt boulders, to at least 18 in. in long diameter, and cobbles and pebbles in a coarse sand matrix. The conglomerate is well-cemented, especially so toward the top, and lies on Newer Volcanics. Fossils are scattered among the clasts and locally concentrated in sandy pockets. Three samples were collected—a single pocket of about 100 cu. in., a 136 cu. in. sample from several pockets, and a skimmed sample from the entire outcrop.

About 725 yds N. of Bank St a drain crosses Princes Highway; 196 ft E. of the highway along the S. side of the drain a section of fossiliferous calcareous sands begins that is exposed for about 30 ft to the E. The column in Fig. 3 was measured near the W. end of the exposure. Newer Volcanics are not exposed in the bottom of the drain, which is about 8 ft above sea level at the outcrop. As is evident from Fig. 3 the sediments consist of lenses of fine silty sands that exhibit differences in texture and sedimentary structures. Some of the chief textural differences are owing to the fossils—whether they are chiefly small and minute or include large shells, and whether they are scattered or are gathered into pockets or lenses.

Lens A was sampled 10 times to gather data on the heterogeneity of species' abundances and on the reproducibility of abundance figures, lenses B and C were sampled once each, and the well-cemented lens D was not sampled. All these samples were of 136 cu. in. However, in preparation they were sieved and approximately 100 gm of the fraction coarser than 1 mm was investigated for each sample. In addition to these quantitative samples, fossils were collected from the outcrop by skimming.

Traced to the E., lens A becomes massive and less fossiliferous, lens B changes aspect as echinoid spines become rare so that it resembles lens C, while lens C becomes crossbedded and the fossils become comminuted so that it is relatively barren of identifiable shells.

E. of this exposure the Quaternary sediments are concealed by slumping for about 71 ft, where they reappear in a poor exposure approximately 38 ft long. Here, lenses exhibit the same range of lithologies as at the westerly outcrop, though not in the same order. A single sample was skimmed from this exposure.

For the purposes of this paper all the samples from Bank St have been pooled and all the samples from the drain have been pooled, so that only two localities are discussed. Statistical assessment of species' abundances within sampled units is incomplete. It will bear on the detailed depositional history of the lenses sampled but should not affect the general environmental and biogeographic conclusions of the present paper, which indeed form a necessary background for the detailed study.

Palaeogeography

The locality at Bank St (Fig. 2) contains a molluscan association that includes many littoral and supra-littoral rocky-shore forms and was probably deposited between the upper littoral zone and the rear of the former beach (see 'Palaeoecology' later). Mean sea level was thus evidently somewhat lower than the exposure when the fossils were accumulating. The locality lies on the nose of a rise of about 6 ft. Perhaps this represents the former beach slope. It is closely comparable to the present slope of the boulder beach at Griffith's Is. By analogy with this recent beach the base of the littoral zone at Bank St may have been about 6 ft below the Bank St conglomerate, or at about 18 ft above present mean sea level. The horizons sampled at the drain lie between 12 and 16 ft above present sea level. If the sands at the drain are associated with the same depositional episode as the conglomerate at Bank St, which is very likely though not proved beyond all doubt, then they were all deposited in waters shallower than 6 ft below about the mean low tide level.

The E.-W. trending basalt ridge on which the conglomerate at Bank St rests formed a peninsula when washed by the sea, or possibly was broken partly into islands. It was at any rate rather analogous topographically to the present Griffith's Is. The conglomerate accumulated on the E. shore of the former point. To the W. the trace of the old shore line must run nearly E.-W. to NW.-SE. To the E. of the former point the sea flooded inland over the lower basalt surface for over a mile and perhaps for a few miles in some areas, forming a more pronounced embayment than the present Port Fairy Bay (Fig. 2). Gill has found marine sediments about 1⅜ miles inland from the present coast along the Moyne R. (Fig. 2). Foraminifera from this locality suggest a lagoonal environment (Collins 1953, sample 3). Fossils at the drain were thus deposited in the lee of a headland on a bottom of silty sand, about 725 yds N. of a rocky shore, and may have accumulated on a broad sand flat in shallow water or on a beach.

The Molluscan Fauna

The invertebrate fauna of the Port Fairy beds is rich and diverse, with representatives of numerous phyla. Foraminifera, Porifera (as spicules), Bryozoa, Annelida, Brachiopoda, Mollusca, Cirrepedia, Ostracoda, Decapoda, and Echinoidea are the groups most abundantly represented. Coralline algal fragments are also present. Only the Mollusca are studied in this report.

TABLE 1

Number of species in Pleistocene molluscan collections from Port Fairy, by classes

CLASS	DRAIN	BANK ST	TOTAL
Polyplacophora	15	2	17
Gastropoda	181	54	193
Scaphopoda	1	0	1
Pelecypoda	80	23	97
Cephalopoda	1	1	1
Total	278	80	309

Table 1 gives the composition of the molluscan fauna by classes at the two localities. Table 2 lists all the molluscan forms collected that are well enough preserved to merit study, with their relative abundances at each locality and their approximate geographic ranges at present. Over 300 species of Mollusca were found in the collections.

The abundance data are based on approximately 500 shells from Bank St and 12,600 from the drain. Much of the material is badly broken, so that in tallying species' abundances an operating definition of what comprises the remains of an individual organism has been necessary for many forms. Among gastropods, a shell or fragment of a shell that includes the apex has usually been counted as a single individual. Other fragments have been noted but are not ordinarily included in the specimen tally, unless only single non-apical fragments, or a few non-apical fragments that could not possibly have come from the same individual, are present. For pelecypods, the possession of a hinge or the presence of hinge fragments has ordinarily been used to tally numbers of valves, unless single non-hinge fragments or a few fragments clearly from different valves are present. As the bivalved pelecypods have two chances per individual to contribute to the fossil record, and as in about half the samples the number of valves of a given species will on the average be odd, the number of individual pelecypods represented by valves of a given species in several samples is computed as $Nv/2 + S/2$, half the number of valves in the collection plus half the number of samples in which the species is found. For polyplacophorans a more direct procedure was followed: in each sample head valves, tail valves, and every multiple of 6 median valves are counted separately for a given species, and whichever count gives the largest result is taken as the number of individuals present.

TABLE 2

List of Pleistocene Mollusca from Port Fairy with relative abundance at each locality and present living distribution

Species abundance symbols are: V (very rare), less than 0·2%; R (rare), from 0·2-0·8%; C (common), 0·8-12·8%; and A (abundant), more than 12·8% of the specimens in the collection. Range symbols are: P, Peronian-ranging; M, Maugean; F, Flindersian-ranging; U, ubiquitous; and D, disjunct. An asterisk following the range symbol indicates that the form is not known to be living at present in the Port Fairy region. Parentheses enclosing the range symbol indicates that the identity of the fossil with the living form is not secure, and the form cannot be given biogeographic weight. For further explanation of range data, see text.

SPECIES	LOCALITY		
	Drain 1	Bank St 2	Present Range 3
POLYPLACOPHORA			
Paricoplax crocinus (Reeve)	V	—	U
Poneroplax albida (Blainville)	—	C	F
Bassethullia matthewsi Pilsbry	V	—	F
Acanthochiton coxi lachrymosus May & Torr	V	—	F
A. gatliffi Ashby	V	—	F
A. kimberi Torr	V	—	U
Autochiton torri (Iredale & May)	V	—	F
Heterozona cariosa Carpenter	V	—	F
H. subviridis Iredale & May	V	—	M*
Haplophax cf. *H. thomasi* Bednall	V	—	(F)
Stenochiton cymodocealis Ashby	R	—	F
Callistelasma meridionalis Ashby	V	—	F
Callistassecla mawleyi (Iredale & May)	V	—	F
Rhyssoplax diaphora (Iredale & May)	V	—	F
R. exoptanda (Bednall)	V	—	F
R. tricostalis (Pilsbry)	V	—	F
Clavarizona hirtosa Blainville	—	C	F*
GASTROPODA			
Schismope pulchra Petterd	V	—	F
Scutus? cf. *S. antipodes* Montfort	V	—	(U)
Notomella candida (A. Adams)	R	—	F
N. dilecta (A. Adams)	V	—	F
Montfortula rugosa (Quoy & Gaimard)	—	R	F
Amblychilepas javanicensis (Lamarck)	R	R	U
A. crucis (Beddome)	R	—	P*
A. oblonga (Menke)	V	—	F
Schismotis laevigata (Donovan)	V	R	F
Marinauris cf. *M. emmae* (Reeve)	V	—	(F)
Notohaliotis cf. *N. ruber* (Leach)	V	—	(U)
Haliotid sp.	V	—	—
Cellana tramoserica (Sowerby)	V	C	U
Patellanax chapmani (Tenison Woods)	R	—	U
P. cf. *P. peroni* (Blainville)	V	—	(U)
Patelloida alticostata (Angas)	V	C	U

Species	Locality		
	Drain 1	Bank St 2	Present Range 3
P. latistrigata (Angas)	R	C	F
Notoacmea granulosa Macpherson	V	—	M
N. scabrilirata Angas	V	—	F
Asteracmea crebristriata (Verco)	R	—	F
A. stowae (Verco)	A	C	F
Naccula? sp.	V	—	—
Clanculus limbatus (Quoy & Gaimard)	V	—	F
C. ochroleucus (Philippi)	V	—	F
C. plebejus (Philippi)	C	C	U
C. cf. *C. flagellatus* (Philippi)	V	—	(F)
Herpetopoma aspersa (Philippi)	V	R	U
H. cf. *H. tasmanica* (Tenison Woods)	V	—	(M)*
Cantharidus pulcherrimus (Wood)	V	C	F
C. kingensis Gabriel	V	—	M*
C. ramburi (Crosse)	C	C	F
Phasianotrochus eximius (Perry)	R	R	U
P. rutilus (A. Adams)	C	—	F
Bankivia fasciata (Menke)	A	R	U
Leiopyrga octona Tate	C	—	F
Thalotia conica (Gray)	V	—	F
Austrocochlea adelaidae (Philippi)	R	R	F
A. concamerata (Wood)	V	C	U
A. constricata (Lamarck)	V	A	U
A. odontis (Wood)	—	R	F
Cantharidella tiberiana (Crosse)	C	—	U
Minopa legrandi (Petterd)	R	—	U
M. petterdi (Crosse)	V	—	F
Gibbula coxi Angas	V	—	U
Calliostoma allporti (Tenison Woods)	V	—	F
Munditia australis (Kiener)	V	—	F
M. subquadrata (Tenison Woods)	V	—	F
M. tasmanica (Tenison Woods)	V	—	F
Subninella undulata (Solander)	V	A	U
Ninella torquata (Gmelin)	V	R	D*
Bellastraea? cf. *B. kesteveni* Iredale	R	R	(P)
Micrastraea aurea (Jonas)	V	—	U
Turbinid sp.	R	—	—
Phasianella australis (Gmelin)	C	—	F
P. ventricosa Swainson	R	—	U
'Pellax' rosea (Angas)	A	—	U
Lodderia lodderae (Petterd)	V	—	U
Pseudoliotia micans (A. Adams)	V	—	U
Elachorbis cf. *E. homalon* (Verco)	V	—	F
Cirsonella weldii (Tenison Woods)	V	—	U
Argalista rosea (Tenison Woods)	V	—	F
Charisma josephi (Tenison Woods)	R	—	F
Dolicrossea labiata (Tenison Woods)	V	—	U
Melanerita melanotragus (A. E. Smith)	V	R	U
Melarapha paludinella (Reeve)	R	—	M

Species	Locality		
	Drain 1	Bank St 2	Present Range 3
M. praetermissa May	—	C	F
M. unifasciata (Gray)	V	A	U
Bembicium nanum (Lamarck)	V	A	U
Laevilitorina mariae (Tenison Woods)	R	R	U
Acmea scalarina Cox	V	—	F
Notosetia cf. *N. atkinsoni* Tenison Woods	V	—	(F)
N.? sp. A.	V	—	—
N.? sp. B.	V	—	—
Pelecydium cylindraceus (Tenison Woods)	V	—	U
Lironoba cf. *L. agnewi* (Tenison Woods)	V	—	(F)
L. tenisoni (Tate)	V	—	U
Pisinna cf. *P. frenchiensis* (Gatliff & Gabriel)	R	—	(M)*
Microdryas australiae (Frauenfeld)	R	—	P*
Merelina hulliana (Tate)	C	—	F
Linemera filocincta (Hedley & Petterd)	R	—	P*
Tatea rufilabris (A. Adams)	V	—	F
Rissoina d'orbignyi (A. Adams)	V	C	M
R. elegantula Angas	C	—	U
Rissolina angasi (Pease)	V	—	P
Eatoniella cf. *E. aurantiocincta* (May)	V	—	(M)*
E. melanchroma (Tate)	R	—	F
Cochliolepas vincentiana (Angas)	V	—	U
Serpulorbis hedleyi (Finlay)	V	—	U
Magilina caperata Tate & May	V	—	U
Zeacumantis diemenensis (Quoy & Gaimard)	V	C	F
Diala semistriata (Philippi)	C	C	M
D. phasianella Angas	V	—	P*
Cacozeliana cf. *C. icarus* (Boyle)	V	—	(F)
C. granaria (Kiener)	A	C	F
Ataxocerithium? sp.	V	—	—
Batillariella estuarina (Tate)	V	—	F
Hypotrochus monachus (Crosse & Fischer)	V	—	U
Cerithiopsis s. l., aff. *C. (Joculator) oessicus* Hedley	V	—	(F)
Seila crocea (Angas)	V	V	U
Zaclys angasi (Semper)	V	—	U
Notosinister ampulla (Hedley)	V	—	U
N. angasi (Crosse & Fischer)	R	—	F
N. armillata (Verco)	V	—	F
N. granifera (Brazier)	R	—	U
N. maculosa (Hedley)	V	—	U
N. pfeifferi (Crosse & Fischer)	V	—	F
N. regina (Hedley)	V	—	U
N. spica Verco	V	—	F
N. tasmanica (Tenison Woods)	V	—	U
Clathrus jukesiana (Forbes)	R	—	U
Limiscala helicornua Iredale	V	—	P*
Melanella sp. A	V	—	—
M. sp. B	V	—	—

Species	Locality		
	Drain 1	Bank St 2	Present Range 3
M. sp. C	V	—	—
M. sp. D	V	—	—
Stylifer petterdi Tate & May	V	—	U
S.? sp.	V	—	—
Hipponix conicus (Schumacher)	R	R	F
Antisabia foliacea (Quoy & Gaimard)	A	A	U
Capulus violaceus Angas	V	—	U
Polinices aulacoglossa (Pilsbry & Venatta)	V	—	P*
P. conicus (Lamarck)	V	—	U
P. cf. *P. sordidus* (Swainson)	V	—	(P)
P.? sp.	C	—	—
Cymatiella lesueri Iredale	V	—	F
C. verrucosa (Reeve)	V	—	F
Litozamia brazieri (Tenison Woods)	—	V	F
Benthozystus petterdi (Crosse)	V	—	U
Gemixystus? cf. *G. laminatus* Petterd	V	—	(P)*
Dicathais baileyana (Tenison Woods)	—	R	F
D. textilosa (Lamarck)	—	R	F
Lepsiella flindersi (A. Adams & Angas)	—	R	F
L. reticulata (Blainville)	V	—	F
L. vinosa (Lamarck)	—	C	F
Macrozafra remoensis (Gatliff & Gabriel)	V	—	(F)
M. cf. *M. angasi* (Brazier)	V	—	U
M. cf. *M. atkinsoni* (Tenison Woods)	V	—	(U)
M. sp. A	R	R	—
M. sp. B	V	—	—
M.? sp.	R	—	—
Zella? cf. *Z. beddomei* (Petterd)	V	—	(U)
Dentimitrella cf. *D. pulla* (Gaskoin)	V	—	(U)
D.? cf *D. tenebrica* (Reeve)	V	—	(M)
Cominella lineolata (Lamarck)	—	C	F
Niotha pyrrhus (Menke)	—	R	F
Reticunassa paupera (Gould)	R	—	F
Parcanassa cf. *P. burchardi* (Philippi)	V	—	(F)
Tavaniotha optata (Gould)	V	—	U
Alocospira cf. *A. monilifera* (Reeve)	V	—	(F)
Eumitra badia (Reeve)	—	R	F
Lyria mitraeformis (Lamarck)	V	—	F
Euliginella shorehami (Pritchard & Gatliff)	V	—	M*
Mesoginella turbinata (Sowerby)	V	—	U
Cryptospira pygmaeoides (Singleton)	V	R	F
Cloisia cf. *C. flindersi* (Pritchard & Gatliff)	V	—	(M)*
Marginellid spp.	R	R	—
Filodrillia columnaria Hedley	V	—	M*
Etrema denseplicata (Dunker)	V	—	F
Guraleus brazieri (Angas)	R	—	P*
G. cf. *G. cuspis* (Sowerby)	V	—	(F)
G. vincentinus (Crosse & Fischer)	V	—	F

SPECIES	LOCALITY		
	Drain 1	Bank St 2	Present Range 3
Euguraleus cf. *E. tasmanicus* (Tenison Woods)	V	—	(F)
Marita bella (A. Adams & Angas)	V	—	F
Heterocithara bilineata (Angas)	V	—	P*
Paramontana modesta (Angas)	V	—	U
P.? cf. *P. tincta* (Reeve)	V	—	(F)
Nepotilla minuta (Tenison Woods)	V	—	P
Turrid spp.	V	—	—
Turrid? sp.	V	—	—
Floraconus anemone (Lamarck)	R	R	F
Pervicacia bicolor (Angas)	V	—	U
Puposyrnola tasmanica Tenison Woods	V	—	U
Syrnola cf. *S. tincta* Angas	R	R	(U)
S. victoriae (Gatliff & Gabriel)	V	R	F
S.? sp.	V	—	—
Cingulina spina (Crosse & Fischer)	R	C	U
C. sp. A	V	—	—
Agatha australis (Angas)	V	R	U
'*Odostomia*' sp.	V	—	—
Chemnitzia acicularis A. Adams	V	R	F
C. mariae (Tenison Woods)	R	—	U
Turbonilla beddomei (Petterd)	V	—	F
Acteon? sp.	V	—	—
Haminoea tenera (A. Adams)	—	R	U
Retusa amphizosta Watson	V	—	F
Cylichnina pygmaea (A. Adams)	R	—	U
Volvulella rostrata (A. Adams)	V	—	U
Acteocina fusiformis (A. Adams)	V	—	U
Edenttellina typica Gatliff & Gabriel	V	—	P
'*Berthelinia typica*' of Burn	V	—	M
Berthellinops serenitas Burn	—	R	M
Marinula zanthostoma H. & A. Adams	V	R	U
Salinator fragilis (Lamarck)	V	—	U
Gadinia cf. *G. conica* Angas	V	R	(P)*
Siphonaria diemenensis Quoy & Gaimard	C	A	U
S. tasmanica Tenison Woods	A	R	F
SCAPHOPODA			
Cadulus vincentianus Cotton & Godfrey	V	—	U
PELECYPODA			
Pronucula hedleyi Pritchard & Gatliff	R	—	U
Scaeoleda crassa (Hinds)	V	—	P
Anadara trapezia (Deshayes)	—	R[1]	U*
Barbatia squamosa (Lamarck)	V	R	F
B. pistachia (Lamarck)	V	—	U
Tucetilla striatularis (Lamarck)	V	R	F
Lissarca rhomboidalis Verco	C	—	F
Notomytilus rubra (Hedley)	R	—	U
Micromytilus crenatuliferus (Tate)	C	R	F

---

[1] Not found in collections at hand but recorded by Gill (in Gill & Fairbridge 1953).

SPECIES	LOCALITY		
	Drain 1	Bank St 2	Present Range 3
Modiolus pulex (Lamarck)	C	R	U
Brachidontes rostratus (Dunker)	V	—	U
B. sp.	V	—	—
Trichomya hirsutus (Lamarck)	V	—	U
Lanistina paulucciae (Crosse)	V	—	F
Gregariella barbatus (Reeve)	V	—	U
Electroma georgiana (Quoy & Gaimard)	V	—	F
Chlamys asperrimus (Lamarck)	V	—	U
Cyclopecten favus Hedley	V	—	U
Cuna delta Tate & May	V	—	M*
C. comma Verco	V	—	F
'*Cuna*' *planilirata* Gatliff & Gabriel	V	—	M*
Cardita calyculata (Linnaeus)	R	R	M
Carditellona cf. *C. elegantula* (Tate & May)	V	—	(M)*
Condylocuna sp. A.	V	—	—
Cyamiomactra mactroides (Tate & May)	V	—	U
Legrandina aff. *L. bernardi* Tate & May	V	—	(M)*
Neogaimardia rostellata (Tate)	V	—	F
N. tasmanica (Beddome)	V	—	U
Diplodonta tasmanica (Tenison Woods)	V	—	U
Numella adamsi (Angas)	R	—	U
Divalucina cumingi (A. Adams & Angas)	V	—	U
Bellucina crassilirata (Tate)	V	R	F
Wallucina assimilis (Angas)	V	—	R
Epicodakia tatei (Angas)	R	R	U
Lasaea australis (Lamarck)	C	A	U
Melliteryx helmsi (Hedley)	R	R	P
Bornia trigonale (Tate)	A	R	F
Marikellia cf. *M. rotunda* (Deshayes)	V	—	(U?)
M. aff. *M. rotunda* (Deshayes)	V	—	(U?)
Lepton australis Angas	V	—	F
L. ovatum Tate	V	—	F
Notolepton antepodium (Filhol)	R	R	M*
N. sanguineum Hutton	V	—	M*
Mylitta auriculata A. E. Smith	V	—	M*
M. deshayesi d'Orbigny & Reeve	V	—	F
M. tasmanica (Tenison Woods)	V	—	U
M. donaciformis Angas	C	R	F
M. aff. *M. donaciformis* Angas	V	—	(F)
Ephippodonta lunata Tate	V	—	F
Pratulum? cf. *P. thetidis* (Hedley)	V	—	(U)
Sunemeroe aliciae (A. Adams & Angas)	V	—	F
Chioneryx cardioides (Lamarck)	V	—	U
Tawera cf. *T. gallinula* (Lamarck)	V	—	(U)
Placamen placida (Philippi)	C	R	F
Bassina aff. *B. pachyphylla* (Jonas)	V	—	(U)
Eumarcia fumigata (Sowerby)	—	R	U
Katylesia cf. *K. peronii* (Lamarck)	V	—	(F)
K. rhytiphora Lamy	—	C	F

SPECIES	LOCALITY		
	Drain 1	Bank St 2	Present Range 3
K.? sp.	V	—	—
Venerupis exotica Lamarck	R	R	F
Pullastra flabagella (Deshayes)	R	—	U
Venerid sp.	V	—	—
Naranio cf. *N. lucinalis* (Lamarck)	V	—	(F)
Donacilla angusta Reeve	R	R	U
Notospisula parva (Petit)	V	—	U
Mactra australis Lamarck	A	R	F
M. pura Deshayes	—	R	F
M. rufescens Lamarck	V	—	F
Deltachion chapmani (Gatliff & Gabriel)	V	—	F
D. electilis Iredale	R	—	F
Plebidonax deltoidalis (Lamarck)	V	—	U
Soletellina biradiata (Wood)	V	—	U
S. donacioides Reeve	V	—	F
Syndesmya exigua (A. Adams)	—	R	F
Tellina albinella Lamarck	V	—	U
Homalina deltoidalis (Lamarck)	—	R	F
H. mariae (Tenison Woods)	V	—	F
Semelangulus tenuiliratus (Sowerby)	V	—	U
Pseudarcopagia victoriae (Gatliff & Gabriel)	V	—	F
Tellinid sp.	V	—	—
Hiatella subalata (Gatliff & Gabriel)	V	—	U
H. australis (Lamarck)	C	R	U
Corbula coxi Pilsbry	V	—	M
Pholas obturamentum Hedley	V	—	U
Bankia? cf. *B. gabrieli* Cotton	V	—	(F)
Myadora tasmanica Tenison Woods	V	—	F
Thraciopsis elongata (Stutchbury)	V	—	P*
CEPHALOPODA			
Mesembrisepia novaehollandiae Hoyle	V	R	F

The ranges of nearly all the species can be conveniently summarized by referring them to the biotic provinces with which they are chiefly associated. Though this practice results in oversimplification it has some justification at the present state of knowledge of the marine biogeography of SE. Australia. Some elements of the fauna which have special geographic patterns are discussed later. In Table 2, forms are referred to as Peronian-ranging (P) if they live today in the Peronian province alone or in the Peronian and Maugean but not in the Flindersian province; Flindersian-ranging (F) if they live in the Flindersian alone or in the Flindersian and Maugean but not in the Peronian; Maugean (M) if they are endemic to Victorian and/or Tasmanian waters; Disjunct (D) if they inhabit the Peronian and Flindersian but not the Maugean; and Ubiquitous (U) if they inhabit all three of these provinces. The present distributions of forms not well identified with living species cannot be specified.

Taxonomy of Mollusca from SE. Australia is unsettled. Some of the difficulties are owing to the somewhat different taxonomic traditions that have arisen among workers in different provinces; some taxa have been erected on biogeographical grounds alone. It would seem to be desirable to document the distinctiveness of such taxa by anatomical or phylogenetic studies before replacing generic names in use elsewhere. Perhaps many of the new names will prove valid but, on present evidence, there seems to be a superfluity, especially of generic names. In the present work no attempt has been made to study taxonomy above the species level. The nomenclature employed by Macpherson & Gabriel (1962) in their comprehensive survey of Victorian Mollusca has been adopted, with a very few exceptions which are noted below.

A major difficulty encountered at the specific and intraspecific levels is in determining the status of closely allied forms for which separate names are available and which are recorded in different regions. They may be identical, or ecologic variants without special biogeographic significance at present, or geographic races or 'subspecies' or distinct species, and they take on markedly different biogeographic significance according to whether they are 'split' or 'lumped'. Neither time nor material has been available to study the living forms, so the convention has been followed of distinguishing among the fossils closely allied forms (whose biological status has not been documented) whenever available morphological criteria permitted—that is, whenever morphological distinctions described among these forms could be unambiguously applied in selecting a name for the fossil.

Identifications have been made chiefly by comparison with specimens in the molluscan collections of the National Museum of Victoria and by reference to original descriptions and monographs. Also some selected material was compared with the collections of the South Australian Museum. Although care has been taken to achieve consistency in identification of the fossils with the living fauna, comparisons with primary type material have been made in relatively few cases.

In view of the taxonomic difficulties it is inadvisable to discuss the fauna in the format of a conventional systematic catalogue. Instead the condition and abundance of each species is discussed in systematic order, with criteria of identification and taxonomic and biogeographic remarks when appropriate. The unqualified term 'minute' is applied herein to specimens which are less than 2 mm in any dimension.

Phylum MOLLUSCA

Class Polyplacophora

Family Lepidochitonidae

Paricoplax crocinus is represented by a single posterior valve from the drain.

Family Mopaliidae

Large median valves of *Poneroplax,* certainly including the species *P. albida,* are common at Bank St. Most are badly worn but coarse wrinkled sculpture and faint brown colour markings are preserved on a few. It is possible that *P. costata* is also represented. Macpherson (in Bennett & Pope 1953) has indicated that *P. paeteliana,* from the Peronian province, seems to be a small race of *P. albida.* The fossils are the large Victorian form.

FAMILY CRYPTOPLACIDAE

Small very rare median valves and a single posterior valve of *Bassethullia mathewsi* were found at the drain. They are chipped but the characteristic longitudinal sculpture is well preserved and one valve is lined with brown zig-zag markings.

At least 3 species of *Acanthochiton* are represented by very rare median valves at the drain. Specimens identified as *A. coxi lachrymosus* have pustules on lateral areas that are elongated into teardrop shapes in rows nearest the jugum, which is striated. Specimens called *A. gatliffi* are very small and have coarser pustulose sculpture on lateral areas than do the other species. The fossils have longitudinally striate jugal areas; the fine pustles present on fresh recent specimens have evidently been eroded. Some recent specimens have similarly eroded jugae. A form identified as *A. kimberi* has a finely granulose jugum and pustules on lateral areas that are fine near the jugum but coarser towards the lateral margin.

FAMILY ISCHNOCHITONIDAE

Autochiton torri is represented by one well-preserved posterior valve from the drain. *Heterozona cariosa* is very rare at the drain; most valves are worn and a few are broken. 6 small, well-preserved posterior valves from the drain are identified as *Heterozona subviridus*. Very rare smooth anterior and median valves from the drain with brownish and greenish-yellow colour stripes are compared to *Haploplax thomasi*.

The small *Stenochiton cymodocealis* is represented by 74 valves from the drain, of which 69 are posterior and 5 are median valves. The cause of this bias is not known. Several of the other chitons are represented by only or predominantly one type of valve, but so few specimens were collected that the bias in these other forms may be due to chance.

A posterior valve of *Callistelesma meridionalis* was found at the drain; the fine network of ridges creating roundish interspaces on the ante-mucronal area distinguishes it from the similar *Callistassecla mawleyi*, which has strong longitudinal ribs on the ante-mucronal area. *C. mawleyi* is very rare at the drain and is represented by median as well as posterior valves; in addition several anterior valves are compared to this form.

FAMILY CHITONIDAE

The genus *Rhyssoplax* is represented by 3 species at the drain, all very rare. A coloured median valve of *R. diaphora* has a few ribs on central areas that shorten medially; a posterior valve was also found. A fragment of a median valve and 2 worn tail valves are identified as *R. exoptanda*. The lateral areas are sculptured with low longitudinal ribs that are interrupted medially by a transverse sulcus. *Rhyssoplax tricostalis*, represented by 2 worn and broken median valves and well-preserved anterior and posterior valves, has 3 or 4 noded radials on lateral areas and strong longitudinal ribs on central areas.

Clavarizona hirtosa (Pl. 3, fig. 1) is common at Bank St, where 30 median and 2 anterior valves were found. They are chiefly badly corroded exteriorly, though the ventral sides are in good condition. The best preserved valves have fine radials on lateral areas and on the jugal area of the second valve as characteristic of this form and retain brown colour patterns. This species is not known to be living in Victoria. It has been recorded from South Australia (Cotton & Godfrey 1940) but recent work suggests that it may be restricted to Western Australia (Womersley & Edmonds 1958, p. 256).

CLASS GASTROPODA

FAMILY SCISSURELLIDAE

Schismope pulchra is very rare in samples from the drain but is represented by several perfect specimens. This species evidently lives offshore and has been dredged in moderate depths (Cotton 1959) although dead shells are recorded in beach deposits.

FAMILY FISSURELLIDAE

Two minute apical fragments from the drain are questionably compared to *Scutus antipodes*.

Notomella is represented by 2 species found only at the drain; *N. candida* (Pl. 3, fig. 2), which is rare, has a ridge connecting apex and posterior slit; and *N. dilecta*, very rare, has a furrow crossed by rather strong lunulae connecting apex and slit and has slightly finer sculpture. Although *N. dilecta* has been recorded from New South Wales it is evidently restricted to the S. and is considered to be an essentially Maugean-Flindersian form. It is not included in Iredale & McMichael's list of New South Wales Mollusca (1962). *Montfortula rugosa*, a robust form with a short notch and with coarser sculpture than either species of *Notomella*, is rare at Bank St. The fossils are the W. Victorian and South Australian form and not the more E. form sometimes called *M. conoidea* (see Iredale 1924).

Amblychilepas javanicensis is rare at Bank St, where it is represented by mature specimens, and at the drain, where only small to minute specimens were found. *A. crucis* (Pl. 3, fig. 3) is a small form with an oval trema that is nearly circular in juvenile shells, and with broad, high, rounded radiating ribs that are obsolete on some specimens, and fine secondary radials. It is represented by small to minute specimens at the drain, where it is rare. Shells of both *A. javanicensis* and *A. crucis* retain much of their original colour patterns. *A. oblonga* (Pl. 3, fig. 4), a small, narrow form with narrow, unequal radiating ribs and an oblong or keyhole-shaped trema, is very rare at the drain.

FAMILY HALIOTIDAE

A few fragments of moderately large shells of *Schismotis laevigata* were found both at the drain and at Bank St. Other haliotids in the collection are very rare minute fragments from the drain, fragments chiefly of apices which commonly have lost the calcitic layer. Many of these cannot be identified. Specimens compared to *Maurinaurus emmae* are exfoliated but have the irregularly swollen spiral ridge, situated between the tremata and the upper suture, that is characteristic of this form. Apical fragments with round tremata, irregular longitudinal rugae and spiral cords are compared to *Notohaliotis ruber*. The material is not adequate to establish whether it is the South Australian form *N. improbulum*, synonymized with *N. ruber* by Macpherson & Gabriel (1962).

FAMILY PATELLIDAE

Large and robust specimens of *Cellana tramoserica* are common at Bank St, but this species is represented only by very rare small and minute shells at the drain. Juvenile shells of *Patellanax chapmani* are rare at the drain. They are oval with moderately strong primary radial ribs and sinuous secondaries ornamenting both primaries and interspaces. Evidently they are not the markedly stellate form *('perplexa')*, though it is impossible to be certain with such small shells. A similar species with lower and straighter secondary radial ribs and the faint remains of a dark colour between the primaries is compared to *Patellanax peroni*. It is very rare at the drain.

FAMILY ACMAEIDAE

Patelloida alticostata is common at Bank St, and very rare stellate juvenile shells from the drain that have black chevron colour patterns between the radials are identified as this form. Small to minute specimens of *P. latistrigata* are common at Bank St and rare at the drain. Some are nearly stellate but have colour patterns of black bars between the radials, as is common in low, heavily ribbed variants of *P. latistrigata*.

2 species of *Notoacmea* are in the collections. *N. granulosa,* with a few coarse granular radial ribs, and *N. scabrilirata,* with numerous fine radial striae, are very rare at the drain. Both retain their colour patterns. *N. granulosa* is known to range to Kangaroo Is. in South Australia but is nevertheless considered here to be a Maugean form.

Asteracmea crebristriata (Pl. 3, fig. 5) is rare at the drain. Though most of the fossils are narrow with flattened, nearly parallel sides, some are wider posteriorly than anteriorly and are broader and relatively lower than typical *A. crebristriata*, suggesting the form called *roseoradiata*. The sculpture of both broad and narrow fossils appears to be similar. Neither form is recorded living in Victoria; they are chiefly South Australian. However, a set of 70 specimens in the Gatliff collection, National Museum of Victoria (No. 4265), labelled Portsea, Victoria, contains *Asteracmea crebristriata*. Many of the shells have rose-coloured radiating rays and are broad posteriorly; others are an even light rose, including a few that are narrow, nearly flat-sided, and high. Possibly these are situs variants; *A. crebristriata* is said to live on *Zostera,* and variability in height, width, and apertural configuration of forms from such a habitat is often high, partly corellating with variability among blades of *Zostera*. *Asteracmea stowae* (Pl. 3, fig. 6) is abundant at the drain and common at Bank St.

A posterior fragment of a minute, smooth, patelliform shell from the drain is questionably identified as a species of *Naccula*.

FAMILY TROCHIDAE

Clanculus limbatus, represented by well-preserved brightly coloured shells, and *C. ochroleucus,* represented by a single worn shell, are very rare at the drain. Coloured apical fragments of *C. plebejus* are common at the drain, and broken mature shells are common at Bank St. A minute apical fragment from the drain is compared to *C. flagellatus*.

A well- preserved mature shell of *Herpetopoma aspersa* was found at Bank St, and fragments of this form are very rare at the drain. 5 small shells of *Herpetopoma* from the drain are compared to *H. tasmanica*. It was not possible to satisfactorily identify several minute specimens of *Herpetopoma* from the drain; they are probably one of the above species.

4 species of *Austrocochlea* are in the collections, all with colours well preserved. *A. adelaidae* is rare at the drain, chiefly as juveniles and minute apical fragments, and rare at Bank St. *A. concamerata* is common and *A. constricta* abundant at Bank St, and each is represented by very rare small fragments and juvenile shells at the drain. *A. odontis* was found only at Bank St, where it is rare.

The small *Cantharidella tiberiana* (Pl. 3, fig. 8) is common at the drain, chiefly as juveniles. *Minopa legrandi* (Pl. 3, fig. 11, 12) is rare at the drain. This minute species is shaped similarly to and broadly overlaps in hue and colour pattern with juvenile *Austrocochlea adelaidae*. However, the latter species has very faint incised spiral lines on young shells (which become rib interspaces on succeeding whorls) and often though not always has a slightly angled periphery, while *M. legrandi* is smooth with a rounded periphery. The purple and white *Minopa petterdi* (Pl. 3, fig. 13) is very rare at the drain.

Gibbula coxi is represented by a few mature and several juvenile shells in samples from the drain. Iredale & McMichael (1962) indicate that *G. bicarinata* A. Adams is the proper name for this species. Very rare minute apical fragments of *Calliostoma allporti* were found at the drain.

Cantharidus pulcherrimus, very rare at the drain and common at Bank St, is represented by mature as well as juvenile shells at both localities. *C. ramburi* is common at the drain and at Bank St; a few mature shells were found but most are juveniles. The minute species *C. kingensis* was recently described from off King Is., Bass Strait (Gabriel 1956) and is not known to be living in Victoria. It is very rare at the drain (Pl. 3, fig. 7). The colours of all 3 species of *Cantharidus* have faded only slightly.

2 species of *Phasianotrochus* have also retained their colours well; *P. eximius*, of which small and minute specimens are rare at the drain and worn mature specimens rare at Bank St; and *P. rutilus*, found only at the drain where small and minute specimens are common.

Bankivia fasciata is represented by mature specimens which are rare and by minute shells including numerous broken apices which are abundant at the drain, and by worn mature shells which are rare at Bank St. *Leiopyrga octona* is common at the drain, most specimens being minute shells. Small specimens of these 2 species have ranges of purplish colour pattern and shape which overlap, but the fine spiral striae of *Leiopyrga* serves to separate it easily from the smooth *Bankivia*. *Thalotia conica* is very rare at the drain; most specimens are of moderate size and are brightly coloured. The E. range end-point of this species may lie in New South Wales, but it is recorded here as an essentially Maugean-Flindersian form.

FAMILY TURBINIDAE

Munditia is represented by 3 species, all very rare at the drain. *M. australis*, although represented only by fragments, is regarded as securely identified since the base of some early whorls is preserved with their characteristic cancellate sculpture and spine-like umbilical projections of axial ribs, reduced to lamellae where crowded near the axis. Good specimens of *M. subquadrata* (Pl. 3, fig. 10) were found. An apical fragment identified as *M. tasmanica* is similar to 2 immature shells in the National Museum of Victoria, No. F8745, from South Australia. This species may live in S. New South Wales (Macpherson & Gabriel 1962) but is tallied here as an essentially Maugean-Flindersian form.

Shells of *Subninella undulata* are abundant and large at Bank St but very rare and chiefly small at the drain. *Ninella torquata* is very rare at the drain and rare at Bank St, large specimens being found at both localities. Calcareous opercula of both these species were found at each locality.

Numerous minute turbinids, apical fragments and juvenile shells, are in the collections from the drain. Discoidal forms without spines and with a double-keeled profile may be *Subninella undulata*. Some of these shells bear a subsutural spiral swelling, and on a few this swelling is defined as a rib and bounded anteriorly by an incised line. Shells with such definite subsutural ribs may be *Ninella torquata*. Minute keeled discoidal specimens with gently convex spires ornamented with noded subsutural ribs and strong triangular spines projecting laterally from the periphery, and with rounded bases bearing 2 or 3 noded spiral cords, are probably *Bellastrea kesteveni*. A shell of this sort was also found at Bank St. However, sufficient juvenile comparative material is not available to confirm these questionable identifications.

A single mature shell of *Micrastrea aurea* was found in float at the drain.

FAMILY PHASIANELLIDAE

Phasianellids are represented in the collections by juvenile shells or small shell fragments, identification of which is difficult. A relatively high-spired species with moderately convex whorls that meet at high angles (chiefly above 140°) at the sutures is identified as *P. australis*. Many specimens have a colour pattern of irregular, vertical, broad, cream and brown stripes, while a few have delicately embroidered spiral colour bands. This species is common at the drain. A lower-spired species with more convex whorls that meet at lower angles (about 100°) is identified as *P. ventricosa*. It is less brightly coloured at Port Fairy, chiefly with faint brown spirals and networks on cream backgrounds. It is rare at the drain.

FAMILY LIOTIIDAE

Lodderia lodderae (Pl. 3, fig. 14) is very rare at the drain. Fine secondary spirals are present between the strong primary spirals. A fragment of the last whorl of a minute species from the drain is identified as *Pseudoliotia micans* (Pl. 4, fig. 18). The characteristic strong beaded spiral ribs, some of which turn anteriorly near the aperture to meet the apertural margin at right angles, the rib-like longitudinal elongations and connections of the beads on the basal spirals, and other sculptural details are believed to make this identification secure.

'LIOTIIDAE'

The minute gastropods, presumably rhipidoglossids, grouped here as 'Liotiidae' have at times been assigned to the liotids but at present reside in various families, the numbers and limits of which are in dispute. They are treated together as a convenience.

Minute rose-tinted specimens of *Argalista rosea* are very rare in samples from the drain. The form identified as *Elachorbis* cf. *E. homalon* (Pl. 3, fig. 15a, 15b) is discoidal and sculptured by variable spiral riblets. On some specimens 1 or 2 of the spirals on the outer part of the base are stronger than the rest. No spirals are as strong as those near the periphery in *E. harriettae*, nor is the sculpture so coarse as in that form. Recent shells identified as *E. homalon* and evidently conspecific with the fossils are in the collections of the National Museum of Victoria, from unknown depths off Wilson's Promontory and from moderate depths off Capes Borda and Jaffa, South Australia (62 and 130 fathoms respectively). This form is very rare at the drain.

Shells of *Cirsonella weldii* and *Dolicrossea labiata* (Pl. 3, fig. 9) are very rare but well preserved at the drain. *Cirsonella australis* Angas is synonymized with *C. weldii* by Macpherson & Gabriel (1962), an arrangement which is followed here, thus extending the range of *C. weldii* into New South Wales. *Charisma josephi* (Pl. 4, fig. 1) is rare at the drain. Many of the shells are worn and corroded so that the fine spirals are erased.

FAMILY NERITIDAE

Melanerita melanotragus is rare at Bank St, where mature specimens in excellent condition were collected, and very rare at the drain, where it is represented by minute shells. Iredale & McMichael (1962) indicate that the correct name for this species is *M. atrementosa* Reeve.

FAMILY LITTORINIDAE

The minute species *Melarapha paludinella* is rare at the drain but was not found at Bank St. On the other hand *Melarapha praetermissa* and *M. unifasciata* are common and abundant, respectively, at Bank St, while only the latter was represented at the drain, by a single small shell. The original colours of all these species, though faded, are clear.

Abundant mature shells of the common *Bembicium* of rock platforms in Victoria, *B. nanum* (see Anderson 1958, Macpherson & Gabriel 1962), were found at Bank St. Their spires are badly eroded but their last whorls commonly retained some sculpture and colour. Living specimens often have similarly eroded shells. Minute juveniles (Pl. 4, fig. 1a, 1b) in excellent condition are very rare at the drain. *Laevelitorina mariae* (Pl. 4, fig. 3) is rare at both localities. Specimens are brown or white and are very well preserved.

FAMILY ACMEIDAE

A single minute worn and chipped shell of *Acmea scalarina* was found at the drain. Probably it is the decollated apex of a larger individual.

'RISSOIDAE'

Treatment of the following minute forms together under this heading is a matter of convenience.

4 specimens from the drain are compared to *Notosetia atkinsoni* (Pl. 4, fig. 7). They are slimmer than recent shells of *N. atkinsoni* in the National Museum of Victoria, including those from Victorian localities at Western Port and Shoreham. Their heights range from 1·4-1·8 mm, the diameter of their last whorls from 1·1-1·2 mm, and their apical angles from about 29°-34°. 2 other species from the drain are questionably referred to *Notosetia* but could not be specifically identified. One, *N.*? sp. A, is represented by a single specimen with a broad 48° apical angle and markedly convex whorls; it is 2·4 mm in height and 1·6 mm in width, the largest shell assigned to *Notosetia*. The other species, *N.*? sp. B, has an apical angle of about 37°, a small aperture and flattened base and gently convex whorls. Two complete shells measure respectively 1·8 by 1·1 and 1·9 by 1·3 mm in height and diameter of their last whorls. All 3 of these forms are very rare.

Pelecydium cylindraceus (Pl. 4, fig. 2) is represented by 2 shells from the drain. The spires of the fossils appear bent, for the whorl anterior to the bend is larger than provided by normal whorl size increase for both previous and subsequent whorls. A single apical fragment from the drain is questionably compared to *Lironoba agnewi*. It has no axial riblets on the 5 whorls that are preserved, and may be a variant of *Linemera filocincta*. These 2 forms may in fact be conspecific, *L. filocincta* being a narrow axially ribbed form. *Lironoba tenisoni* (Pl. 4, fig. 9) is very rare at the drain. Iredale & McMichael (1962) synonymize this form under *L. australis* Tenison Woods.

About 50 specimens of *Pissina* were found at the drain. Most are rather thick-shelled and stout, tinted brown, with traces of a narrow dark brown colour band just beneath the suture. A few have colour bands above the suture as well. These shells closely resemble *P. frenchiensis*, to which they are all compared (Pl. 4, fig. 4, 5). They vary in stoutness, the slimmest resembling *P. tasmanica*.

Well-preserved specimens of *Microdryas australiae* (Pl. 4, fig. 8) are rare at the drain. *Merelina hulliana* (Pl. 4, fig. 12) is common, and *Linemera filocincta* (Pl. 4, fig. 13) rare, at the drain. The brackish-water species *Tatea rufilabris* (Pl. 4, fig. 16) is represented by a single specimen from the drain.

FAMILY RISSOINIDAE

The large, coarsely sculptured, thick-shelled species *Rissoina d'orbignyi* is very rare at the drain, where chiefly small shells were found, and common at Bank St, where several large and unworn shells were collected. *R. elegantula* (Pl. 4, fig. 15) is a smaller form with finer sculpture which is common at the drain; about half the fossils are in good condition and half are worn or broken. *Rissolina angasi* is represented by very rare small shells and fragments at the drain.

Well-preserved dark purple specimens of the minute *Eatoniella melanchroma* are rare at the drain (Pl. 4, fig. 10). A form compared to *E. aurantiocincta* (Pl. 4, fig. 11) is very rare at the drain. It has a broader apical angle and slightly more inflated whorls than recent specimens at hand. Dark reddish-brown subsutural colour bands are preserved on the fossils.

FAMILY TORNIDAE

2 excellent specimens of *Cochliolepas vincentiana* (Pl. 4, fig. 17) are in collections from the drain.

Minute planispiral shells ornamented with close-set annular rings are identified as *Serpulorbis hedleyi*. Another minute form which has tightly-coiled nuclear whorls and an uncoiled, irregular post-nuclear shell is *Magilina caperata*. Both are very rare at the drain.

FAMILY POTAMIDIIDAE

Zeacumantis diemenensis is very rare at the drain, where shells are chiefly fragmental, and common at Bank St, where mature shells in good condition were found.

FAMILY CERITHIIDAE

Diala semistriata (Pl. 4, fig. 19) is common at both localities. Nearly all shells are worn, a common condition among living specimens, but retain traces of their colour patterns. *Diala phasianella* (Pl. 4, fig. 20), which has a much narrower spire than the allied *D. monile*, is very rare at the drain. Spiral colour bands of white and brown spots decorating the lower half of the whorls are preserved on some fossils.

Cacozeliana granaria is abundant at the drain and common at Bank St. The shells are chiefly worn, and are especially concentrated in thin lenses containing other small cylindrical molluscs such as *Diala* and abundant echinoid spines at the drain. *C. granaria* is recorded from New South Wales but is evidently an essentially Maugean-Flindersian form. Minute apical fragments of a slim cerithid with axials slightly predominating in a cancellate sculpture are compared to *Cacozeliana icarus*. They are very rare at the drain.

Ataxocerithium may be represented by a single damaged minute shell from the drain which is slimmer and has a less convex whorl profile and more closely-spaced axials than minute specimens of the common shallow-water species *A. serotinum*. Perhaps the fossil is allied to offshore forms such as *A. scruposum*.

Minute shells of both *Batilleriella estuarina* and *Hypotrochus monachus* (Pl. 5, fig. 1) are very rare at the drain. Colour is well preserved in the latter form.

FAMILY CERITHIOPSIDAE

A broad cerithiopsid represented by a single minute specimen from the drain is similar to small specimens of *Joculator cessicus* in the National Museum of Victoria, F25104, from Western Port but has slightly coarser sculpture. *Seila crocea* is very rare at the drain and at Bank St; shells are chiefly broken and lack apical whorls, so that identification is based on detailed agreement of shape and sculpture between the fossils and recent specimens. The fossils are tinted brown. *Zaclys angasi* is very rare at the drain where it is represented by small worn specimens that retain a light brown tint.

FAMILY TRIPHORIDAE

Although triphorids are not common at Port Fairy, they are diverse; 9 forms are identified with living forms. Most of the fossils retain traces of their original colours, a great aid to identification in this family.

Notosinister ampulla (Pl. 5, fig. 4) is represented by 2 specimens from the drain; they are small with moderately coarse sculpture, anterior and posterior spirals that are nearly equal in strength, and faded brown maculations. *N. angasi* (Pl. 5, fig. 2) has fine sculpture with fairly equal anterior and posterior spirals, a narrow apical angle, and a faded brown colour usually over the entire shell though a few specimens have white maculations near the base. It is rare at the drain. *N. armillata* (Pl. 5, fig. 3) has fine sculpture, a broad apical angle, and flat-sided whorls; at about the 6th whorl, 1½ whorls are brown, forming a colour band around the spire. It is very rare at the drain.

N. granifera (Pl. 5, fig. 7) has fine sculpture, a narrow apical angle, and brown colour maculations; it is rare at the drain. *N. maculosa* (Pl. 5, fig. 6) is coloured much like *N. ampulla* but has coarser sculpture and unequal spirals, the posterior spiral being slightly stronger. It is very rare at the drain.

N. pfeifferi (Pl. 5, fig. 8), rare at the drain, has a narrow apical angle, coarse sculpture, and unequal spirals, the anterior being the stronger. The fossils are white with a faint brown tint apically. *N. regina* is a small pupaeform species with moderately coarse and even sculpture; on relatively large shells the anterior spiral is coloured brown. It is close to *N. ampulla*. A single specimen was found at the drain.

N. spica, represented by a single broken specimen from the drain, nevertheless is firmly identified by the characteristically narrow spire with sub-parallel sides and

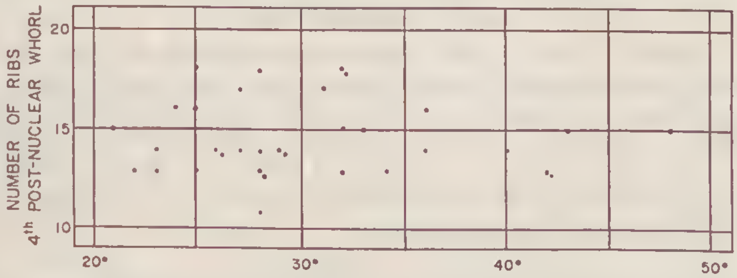


FIG. 4—Relation between apical angle and ribs on fourth post-nuclear whorl of epitonids from Port Fairy.

fine sculpture with anterior and posterior spirals nearly equal. *N. tasmanica* (Pl. 5, fig. 5) is large and evenly granulate on later whorls, for the central spiral rapidly becomes equal in strength to the anterior and posterior spirals. The fossils, rare at the drain, are white.

FAMILY EPTIONIDAE

Small and minute shells of epitonids in the collection fall into 3 groups on the basis of their apical angles: 20-30°; 30-40°; and greater than 40° (Fig. 4). Shells with apical angles greater than 40° were tested to determine the probability that they are from the same 'population' as shells with apical angles less than 40° on the basis of the number or ribs per 4th post-nuclear whorl (Fig. 4). The t-test is used because the variances of the 2 groups are not significantly different based on an F-ratio, and the frequency distributions of rib counts are not greatly skewed. The t value of 2·84 with 32° of freedom shows that the probability of the means of the populations being identical lies between 0·01 and 0·001. Evidently the means are distinct, and on the basis of comparisons with epitonids in the National Museum of Victoria, shells with apical angles of 40° or more are identified as *Limiscala cornuta,* those with a smaller apical angle as *Clathrus jukesiana.* The rib counts of shells with apical angles in the 20's and those in the 30's do not average significantly different, and all are assigned to *C. jukesiana.* On shells of both forms the 1st post-nuclear whorls average between 4 and 5 more ribs than the 4th, with fewer ribs on each succeeding whorl.

FAMILY MELANELLIDAE

Melanellids are very rare in collections from the drain and have not been specifically identified. At least 4 forms are present. One, *Melanella* sp. A (Pl. 5, fig. 9), has a slim spire that is not quite bilaterally symmetrical but curves very slightly, flat-sided whorls, and a long gently curved base. A 2nd form, *M.* sp. B has a straight spire, gently convex whorls and a short base; it is represented by only a single broken specimen. A 3rd form, *M.* sp. C, has a straight slim spire with flat-sided whorls and a short base angulated at its periphery. *M.* sp. D has a bent spire, moderately convex whorls, and a short inflated last whorl and base.

FAMILY STYLIFERIDAE

A single fragment of the spire of a small shell identified as *Stylifer petterdi* was found at the drain. 3 other minute apical fragments from the same locality appear to represent *Stylifer* and may be *S. petterdi* also.

FAMILY HIPPONICIDAE

Hipponix conicus is represented chiefly by well-preserved juvenile specimens; they are patelliform, trapezoidal in apertural outline, with anterior apices twisted towards the left. Some specimens have faint spiral ribs which appear radial in these shells. The juveniles are rare at the drain. A badly worn mature specimen was found at Bank St. *Antisabia foliacea* is abundant at the drain, chiefly as well-preserved small to minute shells but with several mature shells also. It is abundant at Bank St, chiefly as well-preserved mature shells.

FAMILY CAPULIDAE

2 small specimens of *Capulus violaceus* were found at the drain.

FAMILY NATICIDAE

Minute, well-preserved naticids are common at the drain. As most of these shells do not possess well-developed calluses they could not be identified; probably more than one species is represented. 3 minute shells are compared to *Polinices sordidus*. They have a moderately thick parietal callus which narrows below and then expands into a pad which completely covers the umbilicus.

Mature specimens of *Polinices aulacoglossa* and *P. conicus* were found in float at the drain.

FAMILY CYMATIIDAE

Cymatiella lesueri is represented by small and minute worn shells, and *Cymatiella verrucosa* by small apical and apertural fragments. Both forms are very rare at the drain. *C. verrucosa* may range into S. New South Wales but is tallied here as a Maugean-Flindersian form.

FAMILY MURICIDAE

A single small worn shell of *Litozamia brazieri* was found at Bank St. *Benthoxystus petterdi* is very rare at the drain, all specimens being small to minute shells and apical fragments, commonly worn. Very rare minute shells from the drain are questionably compared to *Gemixystus laminatus;* they have close-set axial laminae and compare well with the early whorls of that form.

FAMILY THAIDIDAE

Dicathais baileyana is represented by a large worn shell, and *D. textilosa* by one large and 2 small broken shells, at Bank St. A large well-preserved shell of *Lepsiella flindersi* and common well-preserved shells of *L. vinosa* were found at Bank St. On the other hand very rare small to minute shells of *L. reticulata* were found only at the drain; they retain traces of their original colour patterns.

FAMILY COLUMBELLIDAE

Numerous species of columbellids are in the collections from the drain, and one was found at Bank St. Most of them are represented by minute forms, identification of which is not made with complete confidence, except for *Macrozafra remoensis* (Pl. 5, fig. 10). This form is sculptured by spirally arranged nodes and beads; a row of strong, axially elongate nodes encircles the periphery, a row of smaller rounded beads lies just above the suture, and just below the basal suture and thus visible only on the last whorl is a 2nd row of beads. Specimens of *M. remoensis* are very rare but well preserved at the drain.

The form compared to *Macrozafra atkinsoni* (Pl. 5, fig. 11), very rare at the drain, is probably that species; it is slim with a narrow apical angle, and may be smooth or bear low axial ribs. The apertural profile is characteristic, for the outer lip, after forming a narrow posterior sinus-like reflection, descends anteriorly in a straight line until bending inwards near its rounded anterior margin. The aperture is thus narrow, the last whorl rather flat-sided near the aperture and narrowly shouldered posteriorly.

A form compared to *M. angasi* [which may be called *M. fulgida* (Reeve) according to Iredale & McMichael 1962] is ornamented by 1 or 2 spiral rows of white dots or crescents either just above or just below the suture; all the fossils are smooth. They are very rare at the drain. A slimmer form with similar colour patterns that occasionally bears low axial ribs is called *Macrozafra* sp. A (Pl. 5, fig.

12). It is rare at the drain and at Bank St. Another form called *Macrozafra* sp. B, is broad, with moderately convex, shouldered whorls, sculptured by rather prominent axial ribs; it is very rare at the drain.

A large broad smooth columbellid represented at the drain by several mature shells and evidently by several apical fragments is compared to *Dentimitrella pulla*. A single apical fragment of a less robust form with a smaller nucleus, questionably compared to *D. tenebrica*, is from the drain.

A form compared to *Zella beddomei* (Pl. 5, fig. 10) is represented by very rare small and minute shells and fragments at the drain.

Other unidentified small columbellids are chiefly forms with broad apical angles and convex whorls, more convex than those of any minute specimens of living forms that were available for comparison. These probably represent species of *Macrozafra;* they are rare at the drain.

Family Buccinidae

Cominella lineolata was found at Bank St, where mature shells are common.

Family Nassariidae

Well-preserved mature specimens of *Niotha pyrrhus* are rare at Bank St. A small species of *Reticunassa* is identified as *R. paupera;* it is rare at the drain where many minute and several small shells were found. Minute nassarids sculptured by vertical ribs which are interrupted just beneath the shoulder by a spiral groove (which does not affect the interspaces) are compared to *Parcanassa burchardi*. Somewhat similar shells with noded vertical ribs are identified as *Tavaniotha optata* (Pl. 5, fig. 14). Both these forms are very rare at the drain.

Family Olividae

A single apical fragment of a large olivid which bears traces of spiral sculpture is compared to *Alcospira monilifera*. It was found in float at the drain.

Family Mitridae

A single well-preserved specimen of *Eumitra badia* was found at Bank St. It retains a faint brownish tint. The geographic range of *E. badia* is uncertain (see Macpherson & Gabriel 1962, p. 212) but it is tallied here as a Maugean-Flindersian form.

Family Volutidae

A juvenile shell from the drain that includes a large nucleus and one complete whorl is identified as *Lyria mitraeformis*.

Family Marginellidae

Minute marginellids are rare both at the drain and at Bank St. Most are immature and do not possess those characters, acquired at a later ontogenetic stage, that are necessary for identification. However, a few small specimens from the drain are identified as *Mesoginella turbinata*. They have low axial ribs which are strongest at the shoulder and dwindle to obsolescence anteriorly. A few specimens shaped similarly to the ribbed forms but without sculpture nevertheless are compared to *M. turbinata;* small recent shells of this form with obsolete sculpture are contained in the collections of the National Museum of Victoria. A small, thick-shelled, robust form is identified as *Cryptospira pygmaeoides* (Pl. 5, fig. 17). It is very rare at the drain and rare at Bank St.

A form that, though minute, appears to be mature, is compared to *Euliginella shorehami* (Pl. 5, fig. 16). The fossils, very rare at the drain, closely resemble topotypes of *E. shorehami* in the National Museum of Victoria. A single broken shell from the drain, which lacks a base and outer lip, is compared to *Cloisia flindersi*. The comparison is based on its size, shape, numbers of spiral ribs, and other sculptural details.

FAMILY TURRIDAE

Turrids, chiefly mangeline, are not very common in the collections but are represented by numerous species at the drain. A single well-preserved *Filodrillia* is identified as *F. columnaria*. *Etrema denseplicata* (Pl. 5, fig. 15) is represented by a single minute specimen. This form is considered to be restricted to Victoria and Tasmania, for a closely allied New South Wales form, said to possess weaker axial ribs, has been separated as *E. denseplicata tasmantis* by Laseron (1954).

Guraleus brazieri (Pl. 6, fig. 4), rare at the drain, is the most common turrid at Port Fairy. A single minute shell that is worn and chipped is compared to *G. cuspis*. *G. vincentinus* (Pl. 6, fig. 2), very rare, is represented both by fragments and by small well-preserved shells. A worn apical fragment is questionably compared to *Euguraleus tasmanicus*. It compares well with specimens of that species from Stanley, Tasmania and Lorne, Victoria, National Museum of Victoria collections F25105. A little-known form from New South Wales that is said to be slimmer than typical *E. tasmanicus* has been called *E. tasmanicus peronianus* by Laseron (1954). It is known from 50 fathoms off Montague Is. and seems not to be the form at hand.

Shells of *Marita bella* (Pl. 6, fig. 3), very rare at the drain but the second most common turrid in the collections, are chiefly small and minute although one well-preserved mature shell was found. *Heterocithara bilineata* (Pl. 6, fig. 1) is represented by very rare but well-preserved shells that retain orange colour markings. *Paramontana* is represented by the clathrate *P. modesta*, which is very rare, and perhaps by a single worn shell that resembles *P. tincta*.

A small shell is identified as the daphnelline species *Nepotilla minuta*, described from Tasmania and also recorded from South Australia. A lot in the National Museum of Victoria, F25106, from Portsea, Victoria is evidently *N. minuta* and agrees closely with the fossils.

At least 6 additional species of turrids, which could not be identified, are represented by very rare minute specimens in collections from the drain.

FAMILY CONIDAE

Minute juvenile shells of a cone are rare at the drain. They have moderately high spires and several bear beads at the shoulder. Sufficient comparative juvenile material was not available to confirm their identification but they are compared to *Floraconus anemone*. Large shells of undoubted *F. anemone* are rare at Bank St and were found in float at the drain.

FAMILY TEREBRIDAE

Pervicacia bicolor is very rare at the drain. A few small worn and broken shells from the drain that evidently have flat-sided whorls with little sculpture exhibit the characteristically twisted columella of terebrids but could not be specifically identified.

FAMILY PYRAMIDELLIDAE

Syrnola cf. *S. tincta* is rare at the drain and at Bank St. The columellar plait is weaker among the fossils than among recent specimens of *S. tincta* in the collections of the National Museum of Victoria. *Syrnola victoriae* is very rare at the drain and rare at Bank St. 2 broken shells probably of *Syrnola* from the drain may represent a 3rd species. A single well-preserved shell of *Puposyrnola tasmanica* was found at the drain.

Cingulina spina is common at the drain and rare at Bank St. A robust species of *Cingulina* represented by a single broken shell from the drain has whorls sculptured by 3 broad spiral ribs separated by narrow incised grooves, much like the sculpture of *Seila insignis* (May). However, the form at hand is holostomatous, with a strong columellar plait, and has a broad apical angle. Evidently it is a new species. *Agatha australis* (Pl. 6, fig. 7) is very rare at the drain and at Bank St. Another odostomiine species is represented by minute shells at the drain.

3 species of turbonillines are in the collections, all identified with well-defined living forms: the slim, elongate *Chemnitzia acicularis* (Pl. 6, fig. 9), very rare at the drain and rare at Bank St; *C. mariae,* rare at the drain; and *Turbonilla beddomei* (Pl. 6, fig. 8), very rare at the drain. *T. beddomei,* though provisionally tallied as a 'ubiquitous' form here, may not range into the Peronian province (Iredale & McMichael 1962, p. 85). Iredale & McMichael (1962) imply that the form here called *Chemnitzia acicularis* A. Adams is to be called *C. macleayana* Tenison Woods.

FAMILY ACTEONIDAE

A fragment of a minute shell with fine spiral sculpture appears to be a form of *Acteon.*

FAMILY ATYIDAE

A single small well-preserved specimen of the delicate *Haminoea tenera* was found at Bank St. The fossil is somewhat slimmer than recent shells available for comparison.

FAMILY RETUSIDAE

Rutusa amphizosta (Pl. 6, fig. 6) is very rare at the drain.

A small species of *Cylichnina* (Pl. 6, fig. 5) is rare at the drain. Smaller specimens closely resemble the form called *C. atkinsonii,* said to be a variant of *C. pygmaea* (see Macpherson & Gabriel 1961); larger specimens are somewhat contracted medially, and the largest have an outer lip that flares anterior to the contraction, thus resembling the form called *C. iredaleana.* All the fossils seem conspecific, however, the variations being correlated with size; this species is identified as *C. pygmaea.* The forms of *Cylichnina* living in SE. Australia merit review.

2 chipped specimens of *Volvulella* from the drain are evidently *V. rostrata.* Iredale & McMichael (1962) imply that the correct name for the form at hand is *V. parata* Iredale.

FAMILY SCAPHANDRIDAE

Acteocina fusiformis is very rare at the drain; the fossils are stouter than the specimen illustrated by Macpherson and Gabriel (1961, Fig. 284). Shells of this stout form are labelled *A. apicina* in the collections of the National Museum of

Victoria, a form which Macpherson & Gabriel consider to be conspecific with *A. fusiformis*.

FAMILY BERTHELINIIDAE

An account of the occurrence at Port Fairy of these bivalve gastropods has appeared recently (Valentine 1963). 2 species are present, both of which are very rare at the drain. *Edenttellina typica* (Pl. 6, fig. 10) is represented by one right and 2 left valves. The left valve bears a small protoconch which is inclined towards the opposite valve. The other species (Pl. 6, fig. 11) does not yet have a valid name, but is the form discussed and illustrated as *Berthelinia typica* Gatliff & Gabriel by Burn (1960a). It is represented by one left and one right valve and probably by an additional right valve. The left valve bears an erect and relatively large protoconch (approximately 0·3 mm in vertical diameter). *E. typica* lives in C. Victoria and was found living on the green algae *Caulerpa browni* in the lower littoral zone on the N. side of Griffith's Is., Port Fairy, in February 1963. '*B. typica*' of Burn is not known to live in W. Victoria at present but lives on *Caulerpa scalpelliformis* in C. Victoria and probably ranges up the New South Wales coast at least to Port Hacking (Burn 1960b).

FAMILY PLEUROBRANCHIDAE

A single well-preserved pleurobranch shell from Bank St has kindly been identified by Robert Burn. It is *Berthellinops serenitas* (Pl. 6, fig. 12), recently described from Flinders and known also from Warrnambool (Burn 1962). As the record from Warrnambool demonstrates its presence well W. of the Otways it is not regarded here as extralimital.

FAMILY ELOBIIDAE

A low-spired form of *Marinula zanthostoma* is very rare at the drain and rare at Bank St.

FAMILY AMPHIBOLIDAE

Salinator fragilis is represented by very rare minute shells at the drain. They lack the slight basal angulation usual on large recent shells, as do some small recent shells in the National Museum of Victoria. Some of the fossils retain faint spiral colour bands. A single minute shell from the drain appears to be a *Salinator* or closely related form but is not *S. fragilis*.

FAMILY GADINIIDAE

Small and minute shells compared to *Gadinia conica* are very rare at the drain and rare at Bank St. Probably these are *G. conica*, but it is not always possible to distinguish this form from the South Australian *G. albida* on the basis of such juvenile specimens.

FAMILY SIPHONARIIDAE

Siphonaria diemenensis is abundant at Bank st, where several large and some small to minute shells were found, and common at the drain, where it is represented chiefly by minute shells. The shells retain much of their original colour, with radial ribs brown and interspaces white. *Siphonaria tasmanica* (Pl. 6, fig. 13) is abundant at the drain and a single shell was found at Bank St. All shells are minute juveniles, coloured brown; about one-third of them have corroded apices.

CLASS SCAPHOPODA

FAMILY SIPHONODENTALIIDAE

Well-preserved mature specimens of *Cadulus vincentianus* are very rare in collections from the drain. Iredale & McMichael (1962, p. 97) employ the name *C. acuminatus* Deshayes for the New South Wales form often identified as *C. vincentianus*. If these 2 forms are conspecific, Deshayes's name has priority. The form called *C. vincentianus* herein is conspecific with the common Victorian species identified by that name in the collections of the National Museum of Victoria, and is considered to range into New South Wales.

CLASS PELECYPODA

FAMILY NUCULIDAE

A form identified as *Pronucula hedleyi* (Pl. 7, fig. 1) is rare at the drain. Some small specimens have regular, concentric growth undulae, which are commonly obsolete on larger shells. Faint radial striae are visible on especially well-preserved shells. A few of the valves are paired.

FAMILY NUCULANIDAE

Scaeoleda crassa is represented by small and minute specimens, including paired valves. It is very rare at the drain.

FAMILY ARCIDAE

Anadara trapezia was found by Gill (1953) at Bank St. This form was locally abundant in W. Victoria and E. South Australia at times during the Pleistocene and mid-Holocene, but is not known to be living in those regions at present. It does not occur in the collections at hand.

Barbatia is represented by 2 species that are very rare at the drain: *B. pistachia* which has relatively fine sculpture, and *B. squamosa* which is coarsely sculptured. *B. squamosa* is also found at Bank St, where it is rare.

FAMILY GLYCYMERIDAE

Small, more or less worn glycymerids are rare at the drain and at Bank St. Several of the larger shells, the largest being 10·7 mm in width, exhibit primary radial ribbing overlaid with fine radial striae on a scale identical with the sculpture of *Tucetilla striatularis* (Pl. 7, fig. 2). They have a more circular outline than adult *T. striatularis,* but no juvenile recent specimens were available for comparison. That all specimens at hand are conspecific is not certain.

FAMILY LIMOPSIDAE

The rather elongate *Lissarca rhomboidalis* (Pl. 7, fig. 3) is common at the drain. Most specimens have a faint yellowish tint and are very well preserved.

FAMILY PHILOBRYIDAE

Notomytilus rubra, rare at the drain, is represented by well-preserved rose-tinted specimens. *Micromytilus crenulatiferus* (Pl. 7, fig. 4) is common at the drain and is represented by 4 specimens from Bank St. Most of the shells from the drain have a purplish-red tint, but those from Bank St are white.

FAMILY MYTILIDAE

Modiolus pulex is common at the drain and rare at Bank St. Most shells are small to minute and broken, but only a few are worn and most retain their brown colour. 2 small shells from the drain with radial ribbing are *Branchidontes,* almost certainly *B. rostratus.* Also found at the drain are very rare minute white mytiliform shells about 3 to 4 mm long which have faint, low, irregular radiating riblets (Pl. 7, fig. 5a, b); they are evidently juvenile *Brachidontes,* but closely resemble *Notomytilus rubra* in size and shape.

A single fragment that includes a segment of the posteroventral margin of a large, finely ribbed valve is identified as *Trichomya hirsutus;* the fragment matches recent shells perfectly. *Lanistinia paulucciae* (Pl. 7, fig. 7) is very rare at the drain; some of the fossils retain colour patterns. *Gregariella barbatus* is represented by very rare, chiefly broken shells at the drain.

FAMILY PTERIIDAE

Several minute hinge fragments of *Electroma georgiana* were found at the drain. The presence of this form in New South Wales was not verified by Iredale & McMichael (1961); however specimens from stations in the S. of that State are in the National Museum of Victoria. Evidently it is an essentially Maugean and Flindersian species.

FAMILY PECTINIDAE

A small worn valve of *Chlamys asperrimus* was found in float at the drain, and several chips of a *Chlamys* collected in situ there are probably that species. The small transparent *Cyclopecten favus* (Pl. 7, fig. 8) is very rare at the drain.

FAMILY CRASSATELLIDAE

Cuna delta (Pl. 7, fig. 9) is very rare at the drain. Several specimens consist of articulated valves in excellent condition. A single left valve of a large *Cuna* from the drain is identified as *C. comma* (Pl. 7, fig. 10). The valve is corroded externally so that sculpture is erased, but the hinge is in good condition, and consists of a thick wedge-shaped anterior cardinal, a thin curved posterior cardinal that is convex anteriorly, a thin anterior lateral and 2 thin posterior laterals, the most external of which strengthens into a projecting flange near the beak. The hinge plate is solid and is prolonged posteriorly beneath the laterals.

'Cuna' planilirata (Pl. 7, fig. 11) is very rare at the drain. The dentition of this form suggests that it is allied to *Notolepton* rather than *Cuna.*

FAMILY CARDITIDAE

Cardita calyculata is rare at the drain and at Bank St. Most specimens are small but well preserved.

FAMILY CONDYLOCARDIIDAE

A corroded right valve of *Carditellona* from the drain is compared to *C. elegantula.* External sculpture has been obliterated, but faint radial stripes of the magnitude appropriate to the radial sculptural elements of *C. elegantula* are visible on the interior. The hinge is worn but its elements are identifiable.

A single well-preserved right valve from the drain represents probably a new species of *Condylocuna.* The shell is obliquely ovate, similar to *C. ovata,* and is sculptured by low concentric growth undulae. A worn prodissoconch, small for the genus, is marked off by a ring encircling the beak. There are 2 strong cardinals, the anterior of which is the thicker; both are more robust than the cardinals of *C. ovata*. No anterior laterals can be seen. The valve is 2·3 mm long and 1·9 mm high, slightly larger than recorded sizes among living Australian species of *Condylocuna*.

FAMILY CYAMIDAE

Well-preserved shells of *Cyamiomactra mactroides* (Pl. 7, fig. 12) are very rare at the drain. A worn right valve of a small cyamid is similar to *Legrandina bernardi*. Posterior dental crenulae are strong but anteriorly they are not present; the hinge is somewhat worn however. The anterior cardinal is more nearly parallel to the valve margin than in available recent specimens of *L. bernardi* from Port Albert, Vivtoria, in the collection of C. J. Gabriel. The fossil is stained brown dorsally, as are recent shells of *L. bernardi*.

FAMILY GAIMARDIDAE

Neogaimardia rostellata (Pl. 7, fig. 13) and *N. tasmanica* (Pl. 7, fig. 14) are each represented by very rare but well-preserved specimens at the drain.

FAMILY UNGULINIDAE

Small well-preserved valves of the moderately inflated *Diplodonta tasmanica* are very rare at the drain. *Numella adamsi*, a more robust, compressed shell, is represented by chiefly well-preserved valves, including numerous mature valves; it is rare at the drain.

FAMILY LUCINIDAE

Divalucina cumingi is represented by very rare small and minute shells at the drain. *Bellucina crassilirata*, an inflated form with strong concentric ridges that are radially crenulate, is very rare at the drain and rare at Bank St. Valves are small but well-preserved. *Wallucina assimilis*, with finer concentric ridges than the preceding form, crossed by very fine radial striae, is very rare at the drain though represented by mature shells. Following Macpherson & Gabriel (1962) this form is considered to range from West Australia across S. Australia and into New South Wales. *Epicodakia tatei*, the most abundant of the lucinids at Port Fairy, is rare at the drain, where most shells are small and many are drilled. A single well-preserved mature valve was found at Bank St.

FAMILY ERYCINIDAE

Lasaea australis (*Kellia* of Macpherson & Gabriel 1962) is common at the drain and abundant at Bank St. Valves are chiefly well-preserved and tinted red; those from Bank St are large and robust and include paired specimens. Well-preserved valves of *Melliteryx helmsi* (Pl. 7, fig. 15) are rare at the drain and at Bank St. The hinges and dorsal interiors and occasionally the umboes are tinted rose.

Bornia trigonale (Pl. 8, fig. 2) is the most abundant pelecypod in the collections; it is abundant at the drain, where over 1,800 valves were collected, but rare at Bank St. It is generally well-preserved.

Marikellia is represented by an ovate, moderately inflated form with low umboes and by a markedly inflated form with prominent umboes and with a straight or concave ventral margin. The former is compared to *M. rotunda* (Pl. 7, fig. 17); the latter, which may be a variant of the former, is tentatively identified as *M.* aff. *M. rotunda* (Pl. 7, fig. 16). Specimens labelled *Kellia suborbicularis* from Holdfast

Bay, South Australia, in the Gatliff collection of the National Museum of Victoria (No. 4992) are evidently this latter form.

Lepton australis and *L. ovatum* (Pl. 8, fig. 9) are both very rare at the drain, where they are represented by well-preserved specimens. The genus *Notolepton* is represented by at least 2 species. A relatively large form (the largest specimen is 2·6 mm long, 2·3 mm high) with fine concentric sculpture and a strong hinge with moderately thick cardinals is identified as *N. antepodium*, the type species (Pl. 7, fig. 19). A smaller form (the largest specimen is 2·3 mm long, 2·1 mm high), also concentrically sculptured but with a more delicate hinge with cardinals markedly shorter and more ventrally directed than those of *N. antepodium*, is identified as *N. sanguineum* (Pl. 7, fig. 18). This form is variable in outline, a common variant being elongate anteroposteriorly, and is tinted yellowish or pinkish in the umbonal region. *N. antepodium* is rare at the drain, and a single valve from Bank St is compared to this form. *N. sanguineum* is very rare at the drain. Both are represented by a few paired specimens. In addition to these 2 species, *'Cuna' planilirata* may be referable to *Notolepton*.

3 species of *Mylitta* are present, all very rare at the drain: *M. auriculata* and *M. deshayesi*, each represented by a well-preserved single valve, and *M. tasmanica*, represented by several well-preserved valves and hinge fragments.

FAMILY MONTACUTIDAE

Mysella donaciformis (Pl. 8, fig. 5) is common at the drain and rare at Bank St. A large, flat *Mysella* that is higher, less elongate and less inflated than large specimens of typical *M. donaciformis* is very rare at the drain. It is more sharply truncated anteriorly than specimens of *M. anomala* or *M. ovata* available for comparison, and may be simply a variant of *M. donaciformis*. It is identified as *M.* aff. *M. donaciformis.*

FAMILY GALEOLEMMATIDAE

The unusual minute *Ephippodonta lunata* (Pl. 8, fig. 8) is represented by a single, chipped, smooth valve from the drain. The hinge is well preserved and the identification is regarded as firm. Although *E. lunata* has a finely papillose sculpture when alive, there is a tendency for the thin sculptured layer to exfoliate after death, as noted by Cotton (1938). Valves of this species in the collection of C. J. Gabriel show this tendency clearly. The left valve of smooth paired valves of *E. lunata* in National Museum of Victoria, F25107, from St Vincent's Gulf, South Australia, agrees closely with the fossil.

FAMILY CARDIIDAE

Small worn fragments of shells with cyclodont hinges are very rare at the drain. One of them is questionably compared to *Pratulum thetidis.*

FAMILY VENERIDAE

A single mature valve of *Sunemeroe alicae,* in excellent condition, was found at the drain. A small venerid with dentition typical of *Notocallista* is represented by a single specimen from the drain. The postero-dorsal margin is slightly concave near the beak and then straightens posteriorly, turning down abruptly to form a blunt posterior. The internal margin, except in hinge and ligamental regions, is finely crenulate. External sculpture consists of low concentric growth undulations. This form is evidently not known to be living.

Chioneryx cardioides, represented by small hinge fragments and juvenile shells, is very rare at the drain. Small and minute valves of a *Tawera* compared to *T. gallinula* are very rare at the drain. The dentition and the possession of crenulate margins places this form generically, but specific identification is difficult in this group with such small shells. *Placamen placida* is common at the drain, chiefly as small and minute valves, and is represented by a single broken mature valve at Bank St. An allied form called *P. placida molimen* Iredale has been described from Twofold Bay, New South Wales (Iredale 1925). However, the fossils are considered to represent a Maugean-Flindersian form.

An excellent left valve of a *Bassina* from the drain (Pl. 8, fig. 1) seems allied to *Bassina pachyphylla.* It is relatively lower and more elongate, however, than most recent shells of *B. pachyphylla,* the type of which came from Port Fairy. *Eumarcia fumigata* is represented by a small broken shell from Bank St; the hinge is well-preserved except for a broken anterior cardinal, so that the identification is fairly secure.

Very rare small and minute shells of *Katylesia* from the drain are compared to *K. peroni,* and are probably that species, though specific identification of juvenile *Katylesia* is difficult. Mature but badly broken shells of *Katylesia rhytophora* are common at Bank St.

Venerupis exotica is rare at the drain and at Bank St, being represented chiefly by small valves, a few of which are paired, though all valves from Bank St are large and well-preserved. Some valves are distorted, suggesting a nestling habitat. *Pullastra flabagella* is rare at the drain; many valves are broken and all are small. Although recorded from South Australia by Macpherson & Gabriel (1962) it is not listed by Cotton & Godfrey (1938b) and is evidently an essentially Maugean and Peronian form.

Several minute hinge fragments of venerids from the drain, probably juvenile venerines, represent a few species that could not be identified with previously described forms. Their generally poor condition makes their definition impractical and they are omitted from the list of species.

FAMILY PETRICOLIDAE

A posterior fragment of a minute but rather thick-shelled left valve is compared to *Naranio lucinalis*. The fine divaricating sculpture of narrow ribs crossing to form a reticulate network, and details of the posterior muscle scar and pallial line agree well with specimens of *N. lucinalis* in the South Australian Museum.

FAMILY DONACILLIDAE

Donacilla angusta, represented by a few mature shells and many fragments, is rare at the drain.

FAMILY MACTRIDAE

Mactra australis is abundant at the drain, where it is the most conspicuous species in thin shell seams. Many of the valves are medium to large, though most are small to minute; many are broken. Despite their abundance no paired valves were observed. This form is rare at Bank St, where worn and broken hinge fragments were found.

A large broken right valve identified as *Mactra pura* was found at Bank St; the chondrophore, cardinals, and posterior laterals are preserved and match recent valves of *M. pura*. *Mactra rufescens* is represented by 2 small valves from the drain. The hinge of one is well preserved. This species is recorded in S. New South Wales but is tallied here as an essentially Maugean-Flindersian form.

Notospisula parva is very rare at the drain, where small to minute well-preserved valves are found. This species ranges widely along the S. Australia coast. A form in New South Wales has been separated as *N. parva producta* (Angas). Whatever the validity of this latter form, the typical *N. parva* of Victorian waters, represented by the fossils, is considered to range well into New South Wales.

FAMILY DONACIDAE

Deltachion chapmani is very rare at the drain; the valves are mature and well preserved. *D. electilis* is rare at the drain, chiefly as small and minute or broken shells, though a few mature specimens were found, especially in association with seams of *Mactra australis*. A closely allied form, *D. brazieri* Smith, lives in New South Wales, but the fossils are considered to be identical with the living form that ranges from Western Australia into at least W. Victoria.

Two excellent mature valves of the robust *Plebidonax deltoides* were found at the drain.

FAMILY GARIIDAE

Soletellina biradiata and *S. donacioides* are both very rare at the drain, where they are preserved chiefly as hinge fragments. The latter form is the more abundant.

FAMILY SEMELIDAE

One well-preserved mature valve of *Syndesmya exigua* was found at Bank St.

FAMILY TELLINIDAE

Tellina albinella is represented at the drain by a hinge fragment of a right valve which retains a faint rosy tint. It was originally a large shell, evidently on the order of 1½ in. long. A single large broken valve of *Homalina deltoidalis* was found at Bank St. Small valves of *Homalina mariae*, together with hinge fragments, are very rare at the drain. *Semelangulus tenuiliratus* (Pl. 8, fig. 6) is represented by small but well-preserved shells that are very rare at the drain. *Pseudarcopagia victoriae* is represented at the drain by a small broken left valve with a well-preserved hinge.

FAMILY HIATELLIDAE

Small shells of *Hiatella australis* are common at the drain and rare at Bank St. *Hiatella subalata* is very rare at the drain. This form has been placed in the Thraciidae as *Eximothracia* by Cotton & Godfrey (1938a) and as *Thraciopsis* by Iredale & McMichael (1962).

FAMILY CORBULIDAE

Well-preserved valves of *Corbula coxi* (Pl. 8, fig. 3) are very rare at the drain.

FAMILY PHOLADIDAE

Pholas obturamentum is represented by 2 minute but well-preserved specimens at the drain.

FAMILY TEREDINIDAE

A single right valve of a marine borer from the drain is very questionably compared to *Bankia gabrieli*. It agrees well with specimens from Dunnekin Slip, Port Adelaide, the type locality of *B. gabrieli*, in the National Museum of Victoria. The sculpture of the anterior auricle and anterior median area is exceedingly fine, finer than on available specimens of the other terredinids of Victoria and South Australian waters. The posterior auricle is broken off and the median area chipped. No pallets were recognized among the sediments examined.

FAMILY MYOCHAMIDAE

Small and minute right valves of *Myadora tasmanica* (Pl. 8, fig. 7) are very rare at the drain. They are similar to small valves of *M. pandoriformis* but have stronger sculpture; furthermore the upper surface of the strong antero-dorsal flange forms nearly a right angle with the outer valve surface in *M. tasmanica,* while in *M. pandoriformis* it forms a high angle and the flange itself is not so prominent.

FAMILY THRACIIDAE

Very rare fragile but well-preserved valves of a *Thraciopsis* from the drain are identified as *T. elongata* (Pl. 8, fig. 4). Several hinge fragments presumably of this species were also found.

CLASS CEPHALOPODA

FAMILY SEPIIDAE

Fragments of the gladulus of *Mesembrisepia novaehollandiae* were found both at the drain and at Bank St. That from the drain is a small posterior tip with spine (Pl. 6, fig. 14), while a larger posterior fragment from Bank St includes part of the inner cone and sulcus but lacks the tip. A third fragment of a sepioid gladulus from the drain includes part of the region where the striated and non-striated areas meet; it may be *M. novaehollandiae* also but cannot be certainly identified. Gladuli of *M. novaehollandiae* were common on the Port Fairy beaches during the summer of 1963.

Palaeoecology

GENERAL ECOLOGIC COMPOSITION OF THE FOSSIL ASSEMBLAGES

The general range of habitats from which the fossils at each locality have been derived is clearly indicated by the assemblages. At Bank St, common and abundant forms are those which live today chiefly along open rocky shores. Some species are nearly or completely restricted to intertidal zones at present, as *Poneroplax albida, Clavarizona hirtosa, Cellana tramoserica* and several other limpets, *Melarapha praetermissa* and *M. unifasciata, Bembicium nanum, Lepsiella vinosa*, and *Siphonaria diemenensis.* Others found intertidally are also common in shallow subtidal zones, as *Austrocochlea adelaidae* and *A. odontis, Subninella undulata, Antisabia foliacea, Cominella lineolata,* and *Lasaea australis* (on algae or among mussels). These forms dominate the assemblage, but species that live on algae or marine phanerogams offshore, commonly but not exclusively along rocky coasts, such as *Cantharidus pulcherrimus, C. ramburi,* and *Diala semistriata,* or that are common on sandy bottoms along open coasts, such as *Zeacumantis diemenensis* and *Katylesia rhytiphora,* form important elements. The Bank St association is thus closely similar to associations found today along open rocky coasts. Most of the shells are of medium to large size, with minute forms poorly represented.

The assemblage at the drain, although including many forms that live today in habitats associated with rocky shores, has quite a different aspect. The dominant element, including most of the common and abundant forms, is composed of species that are said to live on algae or marine phanerogams, as *Asteracmea stowae, Cantharidus ramburi, Bankivia fasciata, Leiopyrgia octona, Cantharidella tiberiana, Pellax rosea,* and *Rissoina elegantula.* Other well-represented species are benthonic on sandy substrates in shallow water, and live commonly along sandy beaches that are somewhat protected; *Placamen placida* and *Mactra australis* for example. Common and abundant rocky-shore forms, including *Siphonaria diemenensis* and *S. tasmanica,* are represented chiefly by small and minute shells; in fact, except for *Mactra australis* and a few algae-dwelling gastropods, no species is regularly represented by large shells, the assemblage consisting chiefly of species that are small to minute when mature, young individuals of species that grow to larger sizes, and small fragments of large shells.

In view of the general ecological composition of the two fossil assemblages it is pertinent to review knowledge of molluscan biocoenoses and thanatocoenoses associated with open rocky shores and sandy beaches in W. Victoria and nearby regions at present.

Recent Rocky Shore Biota, W. Victoria and Allied Regions

Fig. 5 represents some aspects of the intertidal zonation of rocky shores in W. Victoria and faunally similar regions—E. South Australia and Tasmania. Bennett & Pope (1953, 1960) and Womersley & Edwards (1958) have given the most comprehensive account of these regions. The term used here for tidal levels and shore zones follow the usage of Bennett & Pope (1953, p. 107) and degree of exposure is also based on the usage of these authors (1960, p. 221). In Fig. 5, column 1 depicts zoning organisms at Portland, Victoria, where exposure is submaximal (modified from Bennett & Pope 1953). It is the locality nearest Port Fairy for which such data have been published. Column 2 represents a 'sheltered' open coast fairly typical of the Maugean province; it is a generalized zonation scheme for N. Tasmania (modified from Bennett & Pope 1960). Columns 1 and 2 are not strictly comparable since different organisms were emphasized in the two reports. Column 3 is the generalized molluscan intertidal pattern found along the N. and NE. sides of Griffith's Is., Port Fairy, in the summer of 1963. In constructing this column the position of the *Galeolaria* zone, taken to indicate the upper part of the lower littoral (lower 'Balanoid') zone, was used as a datum, together with the position of the zone of pure *Melarapha,* taken to indicate the supralittoral ('littorinid') zone. Therefore column 3 does not represent a critical evaluation of the local zonal levels compared with independently determined tidal levels. However, in this case, the use of analogy as a yardstick does not reduce the usefulness of the data for the purposes at hand. Molluscs were emphasized in the construction of this column.

On open rocky shores, both protected and exposed, the supralittoral zone is characterized by the littorinids *Melarapha unifasciata* (usually the highest) and *M. praetermissa.* The upper littoral zone on submaximally exposed open shores is occupied by various limpets (including *Patelloida latistrigata*) and siphonarias (*Siphonaria diemenensis* and *S. tasmanica*) and the carnivorous *Lepsiella vinosa.* The mussel *Modiolus pulex* is often found here, locally forming a band, and *Lasaea australis* is common. In more sheltered open coastal areas, as along N. Tasmania and at Griffith's Is., *Bembicium nanum* (= *B. melanostoma* of Bennett & Pope and at least in part of Womersley & Edwards), *Austrocochlea constricta* (= *A. obtusa* of Bennett & Pope) and *A. concamerata* become common in

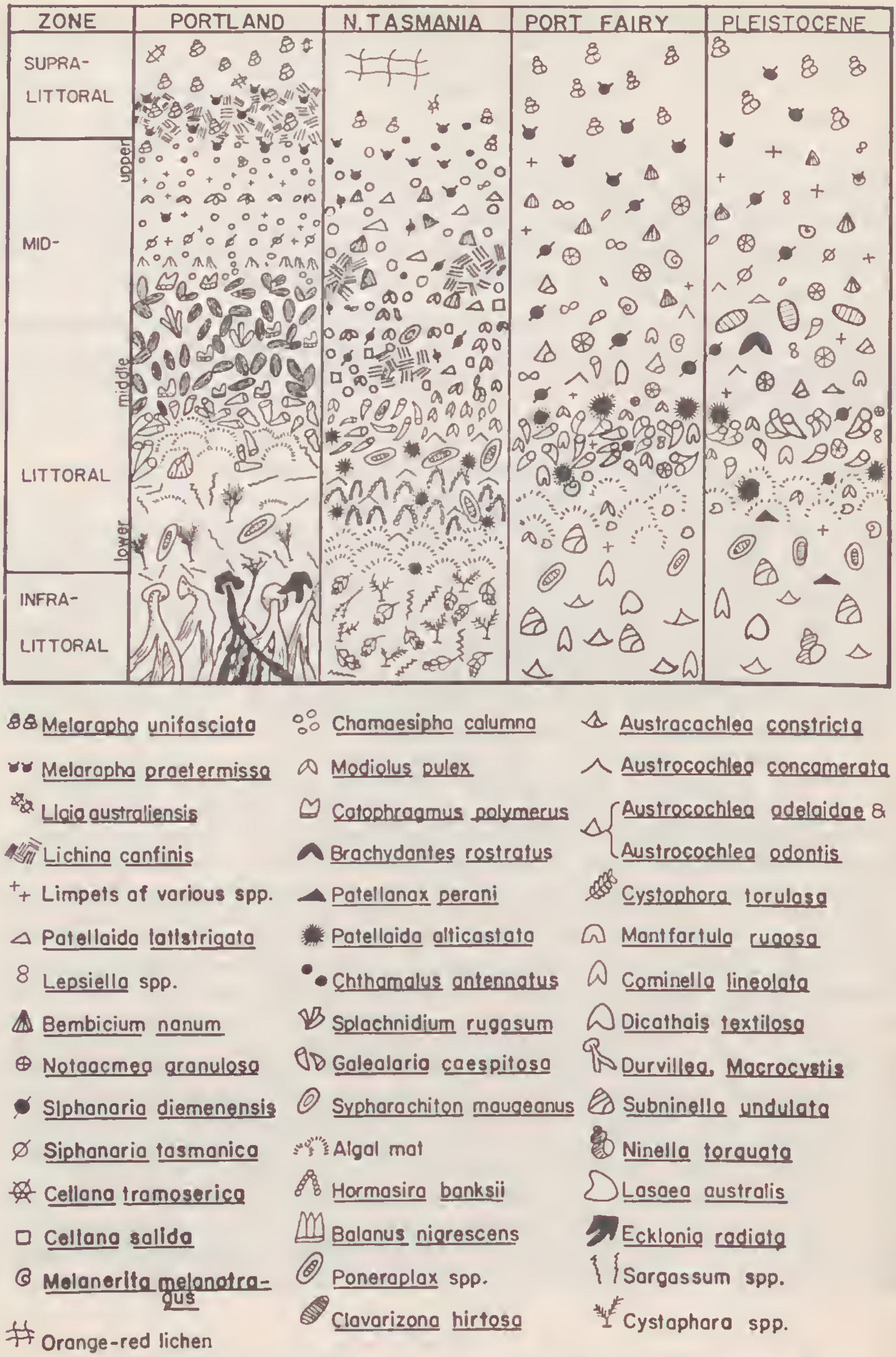


FIG. 5—Intertidal zonation; columns 1 to 3, present zonation at various localities in Maugean province; column 4, inferred intertidal zonation of Pleistocene molluscs respresented in the Part Fairy beds. Column 1, after Bennett & Pope 1953; column 2, after Bennett & Pope 1960.

this zone. At Griffith's Is. the common species of *Lepsiella* in this zone has well-developed axial ribs and therefore a cancellate spire, and is identified as a small form of *Lepsiella flindersi*. On the sheltered coasts the *Modiulus pulex* band is usually absent in this zone, though *M. pulex* may occur in lower zones.

The middle littoral zone in areas of submaximal exposure is often dominated by the mussel *Brachidontes rostratus* (sporadic in Tasmania) and *Lasaea australis* is common. However, on many protected shores *Brachidontes* is reduced or absent (Fig. 5, columns 2 and 3). Instead, *Cellana* and scattered clusters of *Modiolus pulex* may be found, together with species of *Austrocochlea* and *Lepsiella*. *Cominella lineolata* and *Melanerita melanotragus* were especially common in this zone at Griffith's Is.

The lower littoral zone with submaximal exposure is commonly divided into an upper band of *Galeolaria* succeeded below by an algal mat or turf, and below that by a zone with the chiton *Poneroplax*, usually *P. costata*. Living among the *Galeolaria* tubes are various limpets, *Montfortula* and *Lasaea australis*, and the algal mat harbours numerous minute forms. The entire zone is also frequented by several species of trochids, turbinids, and thaidids which range at times into higher zones and also live subtidally. Along more protected shores the fauna changes slightly. *Patelloida alticostata* was especially common just at the top of the *Galeolaria* band at Port Fairy and may be favoured by shelter; it is common in the lower littoral zone of N. Tasmania (Bennett & Pope 1960, p. 189, 193). The chiton *Poneroplax albida* is more often found in the lower parts of this zone at protected localities (May 1923).

A comparison of the algal turf molluscs of exposed and of protected open coasts has not been made, but this fauna deserves special mention here because it assumes some importance in interpreting the Pleistocene assemblages. The 'turf' is composed chiefly of *Corallina* and *Caulerpa*, with other algae, growing in mats and tussocks. Its molluscan inhabitants are numerous and diverse: at Griffith's Is. they include among the gastropods minute scissurellids, trochids, turbinids, liotids, 'rissoids', rissoinids, columbellids, marginellids, and members of most Victorian families of shelled marine opisthobranchs (including berthelinids); and among the pelecypods small and minute limopsids, philobryids, mytilids (including *Modiolus pulex*), cyamids, gaimardids, erycinids (including *Lasaea australis*) and montacutids; and many other molluscan families which are represented by rarer forms. In addition to these very small forms, juveniles of many larger species shelter here, including forms that are commonly found in higher intertidal zones when mature, as several species of *Austrocochlea, Subninella undulata, Bembicium nanum,* and forms that inhabit larger, more offshore algae when mature, as *Phasianotrochus* and *Phasianella*. Young *Bembicium* were also found in pits in basalt boulders in higher zones, but the smallest and presumably youngest individuals were among the algal turf. The matted algae of this zone thus provides habitats for numerous minute species and nurseries for many larger forms. That juveniles of intertidal forms may inhabit lower zones than adults has been noted several times, e.g. by Bennett & Pope (1960, p. 191-193) for several Australian species.

In deep pools and in the shallow sublittoral zone, numerous molluscs are found on rocks (*Austrocochlea adelaidae, A. odontis, Subninella undulata, Dicathais textilosa, Floraconus anemone, Cominella lineolata*), and on some of the larger brown algae (*Cantharidus, Phasianotrochus, Phasianella*). Many of these species, especially those favouring rocks and sandy patches, are not uncommon in the littoral zone proper at some localities.

RECENT THANATOCOENOSES ASSOCIATED WITH ROCKY SHORES AT PORT FAIRY

Intermittently developed at the rear of the basalt boulder beach on the N. side of Griffith's Is. is a thick deposit of shells, evidently thrown up by storms. Shell pockets are also common among the boulders themselves, especially near the top of the beach. The shells are generally large and their matrix when present at all is of pebbles and very coarse sand. A bulk collection was made from a sandy pocket. It contained 455 identifiable shells, which are listed in Table 3.

TABLE 3

Molluscan thanatocoenose from a single sandy pocket, back beach, N. side of Griffith's Is., Port Fairy. Collection includes 455 identifiable shells

SPECIES	ABUNDANCE[1]	REMARKS
POLYPLACOPHORA		
Several unidentifiable valves	C	
GASTROPODA		
Montfortula rugosa (Quoy & Gaimard)	C	
Cellana tramoserica (Sowerby)	C	Large
Patellanax chapmani (Tenison Woods)	R	
Patelloida alticostata (Angas)	R	
P. latistrigata (Angas)	C	
Notoacmea granulosa Macpherson	R	
Clanculus plebejus (Philippi)	C	
Cantharidus pulcherrimus (Wood)	R	Broken
C. ramburi (Crosse)	C	Good
Phasianotrochus bellulus (Dunker)	R	Broken
Bankivia fasciata (Menke)	R	
Austrochochlea adelaidae (Philippi)	C	
A. concamerata (Wood)	C	
A. constricta (Lamarck)	R	
A. odontis (Wood)	C	
Subninella undulata (Solander)	S	78 + 22 opercula
Micrastrea aurea (Jonas)	C	
Phasianella ventricosa Swainson	R	Broken
Melanerita melanotragus (E. A. Smith)	R	Excellent
Melarapha praetermissa May	R	
M. unifasciata (Gray)	C	
Bembicium nanum (Lamarck)	R	
Laevilitorina mariae (Tenison Woods)	R	Excellent
Lironoba tenisoni (Tate)	R	Broken
Pissina cf. *P. tasmanica* (Tenison Woods)	R	Inflated form
Merelina hulliana (Tate)	R	
Rissoina sp.	R	Worn, broken
Eatoniella melanchroma (Tate)	R	
Velacumantis australis	R	Large, broken
Zeacumantis diemenensis (Quoy & Gaimard)	C	
Cacozeliana granaria (Kiener)	C	Large
Opalia australis (Lamarck)	R	Apical fragments
Granuliscala granosa (Quoy & Gaimard)	R	
Hipponix conica (Schumacher)	C	
Antisabea foliacea (Quoy & Gaimard)	A	
Polinices conicus (Lamarck)	R	
Cymatiella verrucosa (Reeve)	R	

[1] For explanation of abundance symbols see Table 2.

SPECIES	ABUNDANCE[1]	REMARKS
Dicathais textilosa (Lamarck)	C	
Lepsiella flindersi (A. Adams & Angas)	C	
L. reticulata (Blainville)	C	
L. vinosa (Lamarck)	R	
Cominella lineolata (Lamarck)	A	
Alocospira petterdi (Tate)	R	
Eumitra australis (Swainson)	R	
E. badia (Reeve)	R	
Proximitra pica (Reeve)	R	
Cryptospira pygmaeoides (Singleton)	C	Worn
Guraleus vincentinus (Crosse & Fischer)	R	
Mitraguraleus mitralis (Adams & Angas)	C	
Floraconus anemone (Lamarck)	C	
Marinula zanthostoma H. & A. Adams	R	Broken
Siphonaria diemenensis Quoy & Gaimard	C	
S. tasmanica Tenison Woods	R	
PELECYPODA		
Lissarca rhombiodalis Verco	R	Hinge fragments
Micromytilus crenulatiformis (Tate)	R	Hinge fragments
Modiolus pulex (Lamarck)	R	Small
Electroma georgiana (Quoy & Gaimard)	R	
Neogiamardia tasmanica (Beddome)	C	1 pair
Lasaea australis (Lamarck)	R	
Melliteryx helmsi (Hedley)	R	
Mysella donaciformis Angas	R	
Donacilla angustata Reeve	R	
Mactra pura Deshayes	R	Large hinge fragments
Deltachion electilis Iredale	R	Broken
Plebidonax deltoidalis (Lamarck)	R	Hinge fragment
Soletellina donacioides Reeve	R	Hinge fragment
Pseudarcopagia? cf. *P. victoriae* (Gatliff & Gabriel)	R	Fragment
Hiatella australis (Lamarck)	R	

Heterogeneity among samples of this size in coarse storm-driven assemblages is doubtless high, and species frequencies cannot be given too much weight. Nevertheless, the Recent thanatocoenose at Griffith's Is. contains common to abundant medium to large specimens of *Cellana tramoserica*, species of *Austrocochlea*, *Subninella undulata*, species of *Melarapha*, *Antisabea*, *Lepsiella*, *Cominella lineolata*, and other forms which are common among the littoral and sublittoral rocks nearby. Algal dwellers such as *Cantharidus* are less common but are present, and *Zeacumantis diemenensis* is common. However, there is also a striking contrast between this thanatocoenose and the molluscan biocoenose of the adjacent shore. Small species such as small limpets, siphonarias, *Modiolus pulex* and *Lasaea* are much rarer than their living representation would merit. The rich minute fauna of the algal turf zone, in fact, is scarcely represented. Thus the larger shells are present in much greater relative abundance than their living representation merits, including species that live only in the lowest littoral or in sublittoral zones. Observation of the shell deposit indicated that this bias would have been even stronger had not a sandy pocket been deliberately chosen for sampling.

TABLE 4

Molluscan thanatocoenose from sandy bottom 100 yds N. of Griffith's Is., Port Fairy

SPECIES	ABUNDANCE[1]	REMARKS
POLYPLACOPHORA		
Acanthochiton coxi lachrymosus May & Torr	V	
Heterozona cariosa Carpenter	V	
Rhyssoplax cf. *R. diaphora* Iredale & May	V	
GASTROPODA		
Amblychilepas javanicensis (Lamarck)	V	
Clanculus plebejus (Philippi)	C	Small & minute
Cantharidus ramburi (Crosse)	C	
Phasianotrochus eximius (Perry)	V	
P. rutilus (A. Adams)	C	
Bankivia fasciata (Menke)	V	
Thalotia conica (Gray)	V	Minute
Austrachochlea adelaidae (Philippi)	V	One large
A. concamerata (Wood)	V	Minute
A. odontis (Wood)	R	Small & minute
Cantharidella tiberiana (Crosse)	C	
Minopa petterdi (Crosse)	V	
Calliostoma allporti (Tenison Woods)	V	
Subninella undulata (Solander)	A	Small
Bellastrea? cf. *B. kesteveni* Iredale	V	Minute
Phasianella australis (Gmelin)	V	Small
P. ventricosa Swainson	R	Small to minute
Pellax rosea (Angas)	V	Worn
Lodderia lodderae (Petterd)	V	
Melarapha praetermissa May	V	Minute
M. unifasciata (Gray)	V	Minute
Bembicium nanum (Lamarck)	V	Minute
Laevilitorina mariae (Tenison Woods)	S	
Pissina frenchiensis (Gatliff & Gabriel)	V	
P. tasmanica (Tenison Woods)	R	
Microdryas australiae (Frauenfeld)	V	
Merelina hulliana (Tate)	V	
Linemera filocincta (Hedley & Petterd)	R	
Rissoina elegantula Angas	V	Small
R. sp.	V	Large for genus
Eatoniella melanchroma (Tate)	S	
Zeacumantis diemenensis (Quoy & Gaimard)	V	
Diala phasianella Angas	V	
D. semistriata (Philippi)	V	
Cacozeliana granaria (Kiener)	R	
Cerithiopsis sp. *s. l.*	V	
Zaclys angasi (Semper)	V	
Notosinister granifera (Brazier)	R	
N. maculosa (Hedley)	V	
N. pfeifferi (Crosse & Fischer)	V	
N. cf. *N. spica* Verco	V	Broken
N. cf. *N. tasmanica* (Tenison Woods)	V	Worn, broken
N. sp.	R	
Clathrus jukesiana (Forbes)	V	
Hipponix conicus (Schumacher)	V	Large to small
Antisabea foliacia (Quoy & Gaimard)	C	Medium to minute
Polinices sp.	V	Minute
Litozamia brazieri (Tenison Woods)	V	

---

[1] Abundances are subjective estimates that species would fall into abundance classes explained in Table 2 if entire collection were identified.

SPECIES	ABUNDANCE[1]	REMARKS
Benthoxystus petterdi (Crosse)	V	
Dicathais textilosa (Lamarck)	V	Minute
Lepsiella reticulata (Blainville)	V	
Macrozafra atkinsoni (Tenison Woods)	R	
M. remoensis (Gatliff & Gabriel)	V	
M. sp. A[2]	V	
M. sp. B[2]	V	
M.? sp.	R	
Zella beddomei (Petterd)	V	
Dentimitrella? cf. *D. pulla* (Gaskoin)	V	Minute, worn
Cominella lineolata (Lamarck)	V	Small
Reticunassa puapera (Gould)	V	
Parcanassa cf. *P. burchardi* (Philippi)	V	
Mitra sp.	V	
Cryptospira pygmaeoides (Singleton)	R	Small
'Marginella' sp.	V	
Guraleus vincentinus (Crosse & Fischer)	V	Small
Euguraleus tasmanicus (Tenison Woods)	R	
Floraconus anemone (Lamarck)	R	Minute
Syrnola victoriae (Gatliff & Gabriel)	V	
Odostomia australis (Angas)	V	
Turbonilla beddomei (Petterd)	V	
T. fusca (A. Adams)[3]	V	
T. mariae (Tenison Woods)	R	
Cylichnina pygmaea (A. Adams)	V	
Acteocina fusiformis (A. Adams)	R	
Midorigai australis Burn[3]	V	Single left valve
Marinula zanthostoma H. & A. Adams	V	Minute
Salinator fragilis (Lamarck)	C	Small & minute
Coxiella striata (Reeve)[3]	V	Minute
Siphonaria diemenensis Quoy & Gaimard	V	Small and minute
PELECYPODA		
Pronucula cf. *P. hedleyi* Pritchard & Gatliff	V	Minute
Lissarca rhomboidalis Verco	V	
Micromytilus crenulatiferus (Tate)	V	
Modiolus pulex (Lamarck)	R	
Cyamiomactra communis Hedley[3]	V	Paired
Neogaimardia tasmanica (Beddome)	R	Paired
Wallucina assimilis (Angas)	V	Small hinge fragment
Lasaea australis (Lamarck)	V	
Melliteryx helmsi (Hedley)	V	
Bornia trigonale (Tate)	V	
Notolepton antepodium (Filhol)	V	
N. sanguineum Hutton	V	
Mysella donacioides Angas	R	Paired
Chioneryx cardioides (Lamarck)	V	Paired
Venerupis exotica Lamarck	R	Paired
Pullastra flabagella (Deshayes)	V	
Mactra australis Lamarck	V	Small hinge fragment
Hiatella australis (Lamarck)	R	

---

[2] Same nomenclature as for fossils.
[3] Not found fossil at Port Fairy.

In a search for shells of the smaller rocky shore molluscs, bottom samples from offshore stations about 100 yds N. of the N. shore of Griffith's Is. were collected by divers of the Victorian Sub Aqua Group. Water depth was between 10 and 14 ft. The bottom was sandy with occasional small boulders, and the water turbid with suspended sediment. Strong currents were encountered. Despite the unexpectedly high energy of the depositional environment the thanatocoenose in these samples contains most of the species observed living in the algal turf zone, with chiefly small specimens of larger species that are common among littoral rocks and offshore algae; plus forms from phanerogams and other habitats. Most of the species in 100 gm of the fraction larger than 1 mm from one of the samples is listed in Table 4. With few exceptions, only species found fossil at Port Fairy are identified. All of the few other forms are rare or very rare. Presumably, samples from still farther offshore at lower energy sites would contain an even larger proportion of small and minute shells.

The Pleistocene Intertidal Zone at Port Fairy

It seems reasonable to assume that the rocky-shore elements dominant in the assemblage at Bank St and important at the drain are biased in the same general ways as the recent thanatocoenoses from the back beach and from offshore at Griffith's Is., respectively. That is, Bank St yields chiefly large shells of larger forms from the former intertidal and subtidal zone and, in fact, resembles the recent back-beach thanatocoenose. The fossil assemblage from the drain, on the other hand, yields chiefly small and minute shells of the rocky shore element, including many species known to inhabit the algal turf zone, as well as littoral rocks and near-shore algae. Insofar as its rocky shore element is concerned, it closely resembles the offshore thanatocoenose though it also includes strong elements not found in the offshore sample in any abundance. From these data, a general picture of the former intertidal zone that contributed to the fossil assemblages can be reconstructed (Fig. 5, column 4). Only molluscs that actually occur in the Port Fairy beds are depicted. Algae, however, are included on the basis of the present habitats and food habits of the molluscs. *Galeolaria* tubes are not uncommon in the Port Fairy beds, especially at the drain.

The former rocky shore is inferred to have been less than submaximally exposed, judging partly from the abundance of *Poneroplax albida, Patelloida alticostata, Bembicium nanum,* and *Siphonaria diemenensis*. The relative abundance of *Modiolus pulex* and relative scarcity of *Brachidontes rostratus* fits this interpretation well. That the beach was not a truly sheltered open coast is suggested by the abundance of *Siphonaria tasmanica* and the presence of *Patellanax peroni* and *Brachidontes rostratus* (which, however, are very rare). It is possible, of course, that rocky-shore elements in the Pleistocene thanatocoenoses, especially at the drain, have been derived from a stretch of coast around the old headland which included rather exposed shores on the weather side and rather protected shores on the lee. Still the predominant aspect of the rocky-shore element suggests moderate exposure, 'when surf without much force constantly washes over the rocks' (Bennett & Pope 1960, p. 221), and this suggestion is not entirely a compromise among conflicting data. Habitats along such a shore could evidently accommodate the entire rocky-shore element. In the reconstructed zonation, species are positioned therefore according to their present patterns on moderately exposed shores.

The supralittoral zone was evidently inhabited by the species of *Melarapha* common there today in the Maugean and Flindersian provinces; *Notolittorina* of the Peronian province is unknown in the Victorian Pleistocene. Upper littoral forms included the characteristic littorine *Bembicium nanum,* species of limpets and siphonarias, and the carnivorous *Lepsiella.* Only scattered occurrences of *Modiolus pulex* are visualized, in keeping with its rareness at Bank St and with the inferred moderate exposure. Species of *Austrocochlea* probably lived here at moist, shaded sites.

Several of these forms were probably common at midlittoral horizons also, where they were joined by *Cellana tramoserica* and the chiton *Clavarizona hirtosa.* This latter species does not live near Port Fairy today, but is said to be a common zoning species of the mid-littoral horizon of Western Australia. *Brachidontes rostratus* is characteristic of this zone, but as it is very rare in the collections it is not depicted as forming a *Brachidontes* band, which is usually a feature of more exposed shores.

The lower littoral zone can be interpreted as very similar to that of the Maugean province today, with a *Galeolaria* band giving way below to an algal turf replete with a diverse minute fauna chiefly represented at the drain. *Modiolus pulex* and *Lasaea australis* were probably most abundant here. That *Caulerpa browni* and *C. scalpelliformis* formed part of the turf association is suggested by the berthelinids collected at the drain. Below the turf a *Poneroplax* horizon is documented by common valves at Bank St. Significantly, no *Poneroplax* from this lowest of intertidal horizons were found at the drain, though small intertidal forms from upper and supralittoral zones are not uncommon there.

The shallow sublittoral zone evidently supported an association of fairly large brown algae ('kelp') with common subtidal forms such as *Subninella undulata, Austrocochlea odontis, Cominella lineolata,* and *Floraconus anemone* on rocks and sand among the holdfasts and with *Cantharidus, Phasianella,* and others on the algae itself. Some of these forms doubtless invaded the littoral zone. *Ninella torquata,* a disjunct Flindersian-Peronian species not known to live in Victoria today, was presumably a member of this association. The large kelp *Durvillea potatorum* unfortunately does not support epizoonts which could serve as fossil witnesses to its former presence, and so we are deprived of evidence on the Pleistocene distribution of this important cool-temperate form.

Although based on present patterns, the relative levels assigned in column 4 of Fig. 5 to characteristic intertidal zoning species such as littorines, limpets, and siphonarias are conjectural; conditions were certainly somewhat different from those of today and this might have resulted in differences in zonation. When changes in relative vertical ranges occur at present they are commonly associated with biological factors. Hewatt (1935) has shown that in Monterey Bay, California, the lower portions of the potential vertical ranges of several intertidal species of limpets and barnacles were occupied by a mussel association, which excluded the former species. When the mussels were removed the limpets and barnacles extended their ranges downward. Cases of the (usually temporary) depletion of mussel beds by predators such as starfish or thaidid gastropods are well documented (Fauvel 1901, Fischer-Piette 1935). What effect the extra-limital forms, e.g. *Clavarizona hirtosa,* might have had on the intertidal position of other species at Port Fairy is not known. The levels of forms with less characteristic zonal distributions, such as trochids and turbinids, vary according to local conditions and the details of their relative positions in column 4 of Fig. 5 should not be taken too seriously.

Despite these uncertainties, the preparation of the column is justified on the grounds that is underlines the essentially Maugean aspect of the rocky-shore element of the Port Fairy beds while, at the same time, it depicts the presence of some extra-limital forms in an ecological context. And since the present marine provinces of SE. Australia are defined almost entirely on the basis of rocky-shore biotas, it provides a useful point of discussion for palaeobiogeographic considerations.

PLEISTOCENE ASSOCIATIONS FROM BEACH AND OFFSHORE BIOTOPES

Descriptions of associations inhabiting offshore biotopes today are not available for Victorian waters. It is necessary, therefore, to rely on scattered information on present habitats of the species found fossil in the Port Fairy beds for interpretation of offshore elements. On the basis of this information the species may be grouped by generalized habitat types into several somewhat theoretical biotopes. For some of the fossils that are most abundant at the drain there is no specific habitat data, and it is necessary to exclude them from consideration in attempting to define the ancient biotopes. However, from such data as is available on their present habitats culled from dredging records and museum labels, and from the general niche occupied by their congeners and to which they are presumably but not certainly adapted, it is possible to suggest their ecological origins once the range of probabilities has been indicated by species for which better data are available.

One element of some importance at the drain is regarded as representing shallow sandy and silty bottoms in moderately quiet water. A characteristic species of this element, and the most abundant form represented by large shells at the drain, is *Mactra australis*, reported to live at low water along sandy beaches (Macpherson & Gabriel 1962) and also as common subtidally. Macpherson has found it especially common off moderately protected beaches such as in Bridgewater Bay where protection from the roughest seas is afforded by Cape Bridgewater (pers. com.). Other forms which may be included in this element are *Scaeoleda crassa, Tucetilla striatularis, Chioneryx cardioides, Tawera gallinula, Placamen placida, Mactra rufescens, Deltachion chapmani, D. electilis, Soletellina biradiata,* and *S. donacioides,* most of which are not common in the Port Fairy beds. Probably some of the naticid and nassariid gastropods belong with this element. Other species may represent this element at its rough-water (*Plebidonax deltoidalis*) and quiet-water (most of the lucinids) extremes.

A second element which includes common and abundant species at the drain has probably been drawn from offshore (submerged) rocky bottoms and associated algal communities. *Bankivia fasciata, Leiopyrga octona,* and *'Pellax' rosea* are common or abundant forms that are evidently fairly characteristic algal dwellers in such biotopes. Large numbers of species that are common along rocky shores today are found also offshore on rocky bottoms, as the large species *Austrocochlea adelaidae, A. odontis, Subninella undulata, Cymatiella verrucosa,* and *Dicathais textilosa,* and numerous small and minute species including many members of the algal turf association. It is not possible to estimate the magnitudes of the contributions from shore and from offshore rocky bottoms, and both habitat types must have made important contributions to judge from the abundance of forms characteristic of each. The characteristic species convey the impression that the rocky shore biotope is quantitatively the more important of the two.

A third molluscan element which can be somewhat arbitrarily distinguished from the others inhabits the marine cryptogams *Zostera, Poseidonia,* and *Cymodocea* in waters of more or less normal salinity. In some situations, cryptogams form submarine meadows in sheltered shallow waters which may extend downward into moderately deep water where light is strong and waters clear. In other cases, cryptogams are present as a patchy or fringing stand interfingering with algae where rocky bottoms give way to finer substrates, especially at sheltered localities. *Stenochiton cymodocialis, Asteracmea stowae. A. crebristriata,* and *Melliteryx helmsi* are evidently especially characteristic of the cryptogam biotope and species of *Zeacumantis, Cacozeliana, Diala,* and *Mysella* are common in this environment, but flourish in other habitats as well. Some of the very abundant forms for which no habitat data are available, such as *Bornia trigonale,* are suspected to belong with this element.

The presence of other elements which are of small importance quantitatively in the Port Fairy beds is indicated by (a) estuarine or lagoonal forms which are usually found living on mudflats and/or among algae or cryptogams, often in brackish water (*Batillariella estuarina, Tatea rufilabris,* and *Melliteryx helmsi*); and (b) a form which has probably come from deeper water than is represented by the other elements (*Cyclopecten favus*).

Fig. 6—Generalized reconstruction of molluscan habitats during deposition of the Pleistocene Port Fairy beds: (1) Bank St; (2) drain.

SUMMARY OF HABITATS

A diagrammatic summary of the biotopes from which the Port Fairy molluscs are believed to have been assembled is presented in Fig. 6. At the point, the rocky shore element indicates moderate protection from waves, suggesting the presence of offshore rocks at shallow depths to break the main force of the waves. Such rocks occur today off Griffith's Is. At some depth offshore, boulders or basalt outcrops are presumed to have supported a rocky-bottom and offshore kelp element. The present basalt outcrops near the beach would have been under between 10 and 20 ft of water during deposition of the Port Fairy beds, a reasonable depth for the submerged rocky-bottom elements. In Fig. 6 the rocky-shore algal association is depicted as interfingering with cryptogams in sheltered spots, and cryptogam meadows may have flourished on appropriate bottoms offshore in relatively quiet water. The stream in the figure is hypothetical in position and is included to depict the presence of a brackish-water habitat. Shallow sandy bottoms N. of the point supported populations of mactrid, donacid and other pelecypods inshore while, offshore, on finer bottoms lived nuculaceans, some lucinids, and others. Details of the distribution of biotope types are not meant to be taken literally.

Feeding Types

The composition of fossil assemblages by feeding type provides evidence of the nature of the original trophic structure and of the environment which supported it. Gastropods, a trophically diversified group throughout the late Mesozoic and Cainozoic, lend themselves well to feeding-type studies.

Gastropods may be conveniently classed in 6 feeding categories. Three are chiefly or entirely of herbivores: browsers, which eat large living plants or masses of small plants; detritus feeders, which eat dead plant material and diatoms; and suspension feeders, whose food is phytoplankton and minute particulate plant detritus. Three other categories are of carnivores: predators, parasites, and scavengers. The relative numbers of gastropod species of these feeding types differ considerably among communities inhabiting certain different environments and probably among certain climatic zones (Valentine, MS in progress).

Table 5

Percentages of feeding types of marine species of shelled gastropods

Feeding Type		Maugean Province	Bank St	Drain
Herbivores:	Browsers	6-10	19-21	12-17
	Detritus Feeders	29	47	44
	Suspension Feeders	3	0	2
Carnivores:	Scavengers	2	2	2
	Parasites	7	9	0
	Predators	48-52	21-23	26-31
Total Herbivores		38-42	66-68	58-63
Total Carnivores		58-62	32-34	37-42

Records of food preferences and feeding methods of Maugean species are few. However, records of feeding habits of numbers of congeneric or at least co-familial species are available from other provinces. From these data, culled from several score references, the most probable feeding habits of each Maugean species has been inferred. In Table 5 are tallied percentages of feeding types of the shelled marine gastropod fauna of the Maugean province, together with the percentages within the two fossil collections from Port Fairy. Documentation for these figures is impracticable here; perhaps the best general references for feeding-type data are Pelseneer 1935, Ankel 1936, and Fretter & Graham 1962. The range of percentage indicated for some feeding types is owing to uncertainties within families which contain forms that have two or more chief feeding habits and for which data are scanty, e.g. the Columbellidae. None of the figures can be exact.

Nevertheless, the differences between the fossil associations and the whole Maugean fauna are striking. About 40% of Maugean forms are herbivores, while about 60% or more of the forms in the fossil assemblages are herbivores. Both browsers and detritus feeders are represented by much greater proportions of species among the fossils. Predator species, on the other hand, are relatively fewer among the fossils—by approximately half. The environment was not an average one for the province, by today's standards at least, but was evidently relatively high in herbivorous niches and low in predatory ones. This suggests the former presence of a varied flora. Of the 8 gastropods that are abundant at either locality all are browsing or detritus-feeding herbivores, and of the 22 forms that are common at either locality, 18 are browsers or detritus feeders, one is a parasite, and 3 are predators (of which one is questionably identified). Thus herbivores are represented by many more specimens than are carnivores, and were more abundant as well as more diversified, suggesting a fairly abundant flora.

Between the two fossil assemblages, the Bank St locality contains more herbivores and fewer carnivores than that at the drain. This suggests that the latter association represents a community which was the poorer in plant variety, or has been assembled from several communities, some of which had few herbivorous types and presumably few plant forms as well.

The relative diversities of feeding types in the Maugean province are similar to those exhibited by other temperate provinces, and relative diversities among the fossil assemblages are well within the range found to be characteristic of rocky-shore and shallow rocky-bottom associations elsewhere (Valentine, MS in progress). Sandy or muddy bottom associations, even in shallow water, often support relatively few herbivorous types and frequently contribute a great diversity of carnivorous types to shallow assemblages. Consideration of feeding-type diversity of the fossil associations thus reinforces the inferences, based on empirical data on habitat preference of the species, as to the nature of the sources of the Port Fairy assemblages.

Biogeography

In discussing biogeographic aspects of the Port Fairy fauna it is convenient to employ provincial terms in use for the present-day open rocky-shore biota: Peronian (Hedley 1904) for the E. coast of New South Wales and N. into S. Queensland; Maugean (Iredale & May 1916, Bennett & Pope 1953, 1960) for Victoria, Tasmania and SE. South Australia; and Flindersian (Cotton 1930) for the South Australian Gulfs, the Bight, and SW. Western Australia. The boundaries, nature and degree of biotic overlap, and distinctiveness of these provinces are not completely understood.

The patterns of currents and water temperatures that presumably control the major molluscan biogeographic pattern in SE. Australia are known in a general way. Recent work by members of the CSIRO (Vaux & Olsen 1961) has demonstrated surface drift patterns which can be partly reconciled with temperature patterns recorded on the charts prepared by the Royal Netherlands Meteorological Institute (1949). Fig. 7, after Vaux & Olsen (1961), depicts surface currents inferred from drift card experiments between the summers of 1958 and 1960; Fig. 8 summarizes average summer (February) and winter (August) isotherms around Australia, taken from RNMI data by Womersley & Edmonds (1958).

For most of the year surface drift along SE. Australia is easterly, bringing waters along shore from the W.; little temperature difference is found along the entire S. Coast of the continent. However, from November to February 1958-59, October to November 1959, and February to April 1960, Vaux & Olsen found a change in the current pattern; relatively warm water entered Bass Strait from the E., and cool southern water drifted northward along W. Tasmania and westward along W. Victoria (Fig. 7a). A body of cool water off W. Victoria and SE. South Australia is evident in the summer isotherms of Fig. 8, and the average annual temperature range is thus small in this region.

FIG. 7—Surface drift pattern off Victoria and Tasmania; A, summer, B, winter. From drift bottle experiments, after Vaux & Olsen 1961.

The biotic change between the Peronian and Maugean provinces is said to be relatively strong, which accords well with the crowding of isotherms along the S. New South Wales coast. On the other hand, the Maugean-Flindersian biotic change is said to occur through a broad transition zone, which the more gradual thermal changes in SE. South Australia may reflect. In addition to these provincial boundaries an intraprovincial biotic change within the Maugean province, centered near Cape Otway, has been described by Bennett & Pope (1953). These authors emphasize that the water bathing W. Victorian shores is often cooler in summertime than along neighbouring shores, and point out that intertidal temperatures may be different from the offshore temperatures recorded in the literature. Although an obvious cool spot does not appear in Fig. 8, persistent local temperature differences that may be biologically important are often masked in generalized isothermal patterns. More precise data are evidently necessary to document the basis of this intraprovincial biotic change.

The biogeography of species in the Port Fairy beds may be conveniently discussed with reference to the patterns outlined above. All but two of the 234 forms that are firmly identified with fairly well-defined living species inhabit the Maugean region today and all but three are recorded from Victorian waters. Most of these species live in other provinces as well. About 40% range from the Flindersian through the Maugean and well into or through the Peronian and hence are ubiquitously distributed as far as interpretation of the Port Fairy beds is concerned.

About 47% are known to be living only in the Flindersian and Maugean provinces and do not range into the Peronian. Some of these forms are recorded from only as far E. as W. Victoria, while numbers of them range as far as Western Port. Several are known to live E. of the Western Port district, and a few of these are found in bays in S. New South Wales (e.g. *Electroma georgiana*), which is Peronian as far as the open rocky shore biotope is concerned. In habitats other than rocky shores, the position and nature of the provincial change are less well known, and in view of their essentially W. ranges these few forms are regarded here as Flindersian-Maugean types.

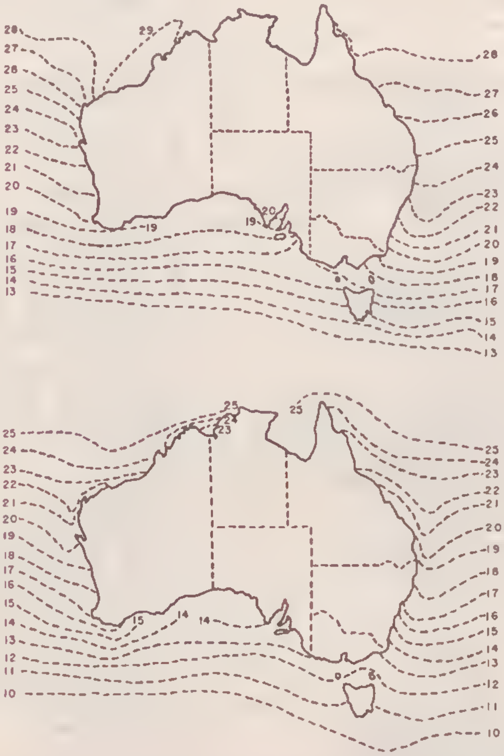


FIG. 8—Surface isotherms around Australia: upper, Summer (February) average; lower, winter (August) average. After Womersley & Edmonds 1958.

Only about 6% of these species live in the Peronian and Maugean provinces but not in the Flindersian. Many of these live in embayments along the Gippsland coast and in Western Port and Port Phillip, but are not known living in W. Victoria, so that their fossil occurrences at Port Fairy lie outside their present known ranges. A few forms tallied as Peronian-Maugean types do reach the Port Fairy district today, and some even live along the SE. coast of South Australia, S. of about Kangaroo Is.; however, their essential E. ranges are patent.

A modest 7% consists of endemic Maugean species, most of which are not known to live in W. Victoria. One form (*Cantharidus kingensis*) is not recorded outside Tasmanian waters, though it is known from King Is., Bass Strait. Finally, there are the two species discussed previously, *Clavarizona hirtosa* and *Ninella torquata*, which evidently do not live in the Maugean province at all today.

Marine temperatures are known to be a major factor in limiting the ranges of marine molluscs. Although for a given species there are certainly thermal limits beyond which it cannot support populations, the actual range end-points at any

TABLE 6

Recent species identified or compared with forms in the Port Fairy beds which are not known to include Port Fairy within their living ranges ('extralimital' forms)

SPECIES	RECORDED LIVING RANGE
POLYPLACOPHORA	
Heterozona subviridus Iredale & May	C. Vict., Tas.
Clavarizona hirtosa (Blainville)	Wtn Aust.; W. Sth Aust.?
GASTROPODA	
Amblychilepas crucis (Beddome)	C. Vict., N. Tas.
Herpetopoma tasmanica (Tenison Woods)	C. Vict., Tas.
Cantharidus kingensis Gabriel	King Is.
Ninella torquata (Gmelin)	N.S.W., Sth Aust., Wtn Aust. (but not Vict. nor Tas.)
Pissina frenchiensis (Gatliff & Gabriel)	C. Vict., Tas.
Microdryas australiae (Frauenfeld)	N.S.W., E. & C. Vict., Tas.
Linemera filocincta (Hedley & Petterd)	N.S.W., E. Vict., Tas.
Eatoniella aurantiocincta (May)	C. Vict., Tas.
Diala phasianella Angas	N.S.W., E. & C. Vict.
Limiscala hemicornua Iredale	N.S.W., E. & C. Vict., Tas.
Polinices aulocoglossa (Pilsbry & Vanatta)	Qld., N.S.W., E. & C. Vict., Tas.
Gemixystus laminatus Petterd	N.S.W., Tas.
Euliginella shorehami (Pritchard & Gatliff)	C. Vict.
Cloisia flindersi (Pritchard & Gatliff)	C. Vict.
Filodrillia columnaria Hedley	C. Vict., Tas.
Guraleus brazieri (Angas)	N.S.W., E. Vict., Tas.
Heterocithera bilineata (Angas)	N.S.W., E. Vict., Tas.
Puposyrnola tasmanica (Tenison Woods)	N.S.W., E. Vict., Tas.
Gadinia conica Angas	N.S.W., E. & C. Vict., Tas.
PELECEPODA	
Anadara trapezia (Deshayes)	N.S.W., E. & C. Vict., Wtn Aust. (but not W. Vict. nor Sth Aust.)
Cuna delta (Tate & May)	C. Vict., Tas.
'Cuna' planilirata Gatliff & Gabriel	C. Vict., Tas.
Carditellona elegantula (Tate & May)	C. Vict., Tas.
Legrandina bernardi Tate & May	C. Vict., Tas.
Notolepton antepodium (Filhol)	C. Vict.
N. sanguineum (Hutton)	C. Vict.
Myllita auriculata Smith	C. Vict., Tas.
Thraciopsis elongata (Stutchbury)	N.S.W., E. & C. Vict., Tas.

time may be determined by other factors—physical habitat failure, biotic competition of some sort (the geography of which may or may not be partially thermally controlled itself), and so on. Since the factors that actually determine the range end-points of the individual species under consideration have not been studied, it is not certain to what extent their present ranges are temperature-controlled. Furthermore, there is no assurance that some of these forms have not evolved new temperature adaptations since deposition of the Port Fairy beds. Thus, climatic inferences based on their range changes must be regarded as provisional.

The present recorded distributions of species not known to include the Port Fairy region in their present ranges—'extralimital species'—are listed in Table 6; the list will probably be eroded by range extensions as more collecting is done. Of these extralimital forms 12 range from New South Wales into Tasmania but not into W. Victoria, although 7 are known from E. Victoria. Factors that prevent their dispersal into W. Victoria are not known, but they are obviously not frigophilic (cool-water types) relative to W. Victorian water temperatures. Many of them are small forms whose ranges may be incompletely known. *Polinices aulocoglossa,* however, is a larger species; in Tasmania it is restricted to the N. coast (May with Macpherson 1958). It is possible that *P. aulocoglossa* and some other species of this element are excluded from W. Victoria by low temperatures, and harbour in local warm spots in C. Victoria and Tasmania.

9 of the extralimital forms that do not range into New South Wales live in C. Victoria and Tasmania, and 6 more live only in C. Victoria. The thermal significance of these species relative to E. Victorian waters is obscure. However, if the several extralimital species reaching C. Victoria from New South Wales are not regarded as frigophiles, then the C. Victorian and N. Tasmanian endemics may not be frigophilic either, unless peculiarities of habitat or distribution restrict them to cooler sites. No such restriction is evident from available collecting records.

Bennett & Pope (1960) have described the chief faunal differences in characteristic exposed-shore forms between Tasmania and the mainland. Among Tasmanian molluscs the chief differences are: *Melarapha praetermissa* is numerically equal or dominant to *M. unifasciata; Cellana solida* is abundant, but *C. tramoserica* is absent; *Notoacmea mayi* is more common; and *Sypharochiton maugeanus* is present. *C. solida, N. mayi*, and *S. maugeanus* were absent as fossils at Port Fairy, *C. tramoserica* was present, and *M. unifascisata* was more abundant than *M. praetermissa.* Thus, despite the presence of extra-limital species that range into Tasmania today, there was no clear tendency towards the establishment of species characteristic and important along S. shores at present.

Thus, among extralimital forms, there is a small N. probably thermophilic element (*Clavarizona, Ninella*), a larger element which does not range W. of the Otway Mountains today which probably includes some thermophiles, and a small element the thermal significance of which is too equivocal to support speculation. All of this distributional evidence is admittedly somewhat equivocal but, on balance, it suggests a marine climate little or no cooler than today and probably a bit warmer.

Since the modernity of the Port Fairy fauna precludes a preglacial age, and its thermal aspect suggests a mild climate, it may well be a interglacial fauna. Consider the probable effects of a period of cool marine climates visualized as occurring after the Port Fairy fauna lived and related to (at least) the last major continental glaciation. Relatively thermophilic species or ecotypes would have then been eliminated from the Victorian littoral and sublittoral with a possibility of some hardier forms remaining as replict populations at especially favourable localities. At the same time relatively frigophilic forms would have immigrated from the S. In Australia, fossil records of the resulting faunas are expectable only offshore today due to the lowered sea levels of glacial times. No such faunas are now known from off Victoria, although they are known off other coasts, including some in the Mediterranean (Mars 1959).

Rewarming associated with the close of the last glacial age would be expected to eliminate frigophiles, again except for possible relict populations in refugia, and to allow immigration of thermophiles. Since the cool climates were probably considerably cooler and the warm climates only a little warmer than today, frigophilic relicts would be more likely during interglacials than thermophilic relicts during glacials. Small but biologically significant post-glacial climatic fluctuations are well known also.

Glacial-associated cooling is inferred to have eliminated species such as *Clavarizona hirtosa, Ninella torquata, Anadara trapezia, Polinices aulocoglossa* and others from W. Victoria. Some of these forms may have reappeared during the 'mid-Holocene', but none of the molluscan assemblages of that age has been extensively studied. *A. trapezia* and *N. torquata* have widely disjunct distributions today, although it may well be that limiting factors other than temperature are restricting their present ranges (as suggested for *A. trapezia* by Kendrick & Wilson 1959). Thus, the fauna of the Port Fairy beds represents only a passing phase in a changing system, as does the present Maugean fauna, and perhaps neither of these faunas achieved equilibrium with its associated climate.

The Port Fairy fauna seems to suggest a temperature rise of about 1-2°C, which may have been only seasonal. If the summer flow of cool S. water (Fig. 7) were eliminated or modified, a shift of mean isotherms of about this magnitude should result (Fig. 8). A climatic model that involves a slight rise in winter temperatures also would help to account for the thermophiles in a more convincing manner but requires that evidence from S.-ranging species be given less weight than that from N.-ranging species. Although there is some slight theoretical justification for this, as noted above, it is really special pleading at the present state of knowledge. A slight extension of the present mean temperature range at Port Fairy involving a summer rise of about 2°C results in a satisfactory climatic model.

Faunal Comparisons and Correlation

Fossil molluscan assemblages that resemble those at Port Fairy in species composition and in general modernity are known from other localities in Victoria, and from South Australia and Tasmania.

In South Australia, particularly in the lower SE., a series of former high sea-stands is recorded by calcareous terrace and dune complexes which form a series of parallel 'ranges' well described by Sprigg (1952). The general aspects of fossil assemblages associated with these sea-stands are recounted by Crocker & Cotton (1946) and Sprigg (1952). Crocker & Cotton in particular describe the environmental significance of 4 associations: fine sand beach, estuarine beach, 'reef' (the term reef being applied to firm wave-resistant inorganic shallow bottoms), and 'weed' (forms that live chiefly on algal and cryptogam substrates). Unfortunately, detailed faunal lists of the fossil assemblages are not recorded. However, forms specified as characteristic of 'reef' and 'weed' assemblages include many species found in the Port Fairy beds.

The presence of the extralimital *Anadara trapezia* in South Australia has long been noted (Howchin 1912, 1923). In the SE. it is found within one of the younger ranges (Woakwine range: Hossfeld 1950) as well as in deposits of a late high sea level that flooded the flats between the lower ranges. These late deposits are packed with *Anadara* in appropriate facies.

In Tasmania, Macpherson has identified Quaternary molluscs from low terrace deposits on King Is. (Jennings 1959). They are modern associations which resemble the Port Fairy assemblages insofar as their general ecological background is similar. No extralimital forms were found. *Anadara trapezia* is recorded from Tasmania (May 1921), probably as a fossil, but its provenance is not certain.

In the Victorian Quaternary, extralimital species are known to occur in at least two stratigraphic contexts: in assemblages associated with calcareous sediments that are too old for radiocarbon age estimates, but which are of distinctly modern aspect, such as at Port Fairy and Port Campbell (Baker & Gill 1957), and in younger sediments which Gill (1954, 1956) has shown by radiocarbon methods to be on the order of 5,000 years old. The Port Fairy beds evidently represent an E. extension of conditions similar to those prevailing during deposition of the lower 'ranges' in SE. South Australia. Thorough documentation of the South Australian molluscan assemblages is desirable as a prelude to more detailed correlation. Quaternary biostratigraphy is so complicated by sea level fluctuations, minor tectonic events, and faunal migrations that further correlations even of a general nature are not attempted until more data are available.

References

ANDERSON, HILDA, 1958. The gastropod genus *Bembicium* Philippi. *Aust. J. Mar. Freshw. Res.* 9: 546-568.

ANKEL, W. E., 1936. Prosobranchia. In Grimpe, G., & Wagler, E., Die Tierwelt der Nord- und Ostsee. *Leipzig, Akad. Verlagsgesellschaft* 9: 1-240.

BAKER, GEORGE, 1944. The geology of the Port Campbell district. *Proc. Roy. Soc. Vict.* 56: 77-108.

———, 1950. Geology and physiography of the Moonlight Head district, Victoria. ibid. 60: 17-42.

———, 1953. The relationship of *Cyclammina*-bearing sediments to the older Tertiary deposits south-east of Princetown, Victoria. *Mem. nat. Mus. Vict.* 18: 125-134.

BAKER, GEORGE, and GILL, E. D., 1957. Pleistocene emerged marine platform, Port Campbell, Victoria. *Quaternaria* 4: 1-14.

BENNETT, ISOBEL, and POPE, E. C., 1953. Intertidal zonation of the exposed rocky shores of Victoria, together with a rearrangement of the biogeographical provinces of temperate Australian shores. *Aust. J. Mar. Freshw. Res.* 4: 105-159.

———, ———, 1960. Intertidal zonation of the exposed rocky shores of Tasmania and its relationship with the rest of Australia. ibid. 11: 182-221.

BOUTAKOFF, N., 1952. The structural pattern of south-west Victoria. *Min. and Geol. J.* 4 (6): 21-29.

BUREAU OF MINERAL RESOURCES, 1960. Summary of oil-search activities in Australia and New Guinea to June 1959. *Bu. Min. Res. Rept* 41A: 1-68.

BURN, ROBERT, 1960a. Australian bivalve gastropods. *Nature* 187: 44-46.

———, 1960b. Occurrence of bivalve gastropods along the coastline of New South Wales. ibid. 188: 680-681.

———, 1962. On the new pleurobranch subfamily Berthellinae (Mollusca: Gastropoda); a revision and a new classification of the species of New South Wales and Victoria. *Mem. nat. Mus. Vict.* 25: 129-148.

CHAPMAN, F., 1925. Tertiary fossils from bore cores, Port Fairy. *Rec. Geol. Surv. Vict.* 4: 481-483.

COLLINS, A. C., 1953. Pleistocene Foraminifera from Port Fairy, western Victoria. *Mem. nat. Mus. Vict.* 18: 93-105.

COTTON, B. C., 1930. Fissurellidae from the 'Flindersian' region, southern Australia. *Rec. S. Aust. Mus.* 4: 219-222.

———, 1938. *Ephippondonta*—South Australia's most peculiar bivalve shell. *Vict. Nat.* 55 (4): 58-61.

———, 1959. South Australian Mollusca. Archaeogastropoda. *Govt. Printer, Adelaide:* 1-449.

COTTON, B. C., and GODFREY, F. K., 1938a. The Molluscs of South Australia, Part I. The Pelecypoda. ibid.: 1-314.

———, ———, 1938b. A systematic list of the Gastropoda. The marine, freshwater, and land univalve Mollusca of south and central Australia. *Malac. Soc. S. Aust. Pub.* 1: 1-44.

———, ———, 1940. The Molluscs of South Australia. Part II. Scaphopoda, Cephalopoda Aplacophora and Crepipoda. *Gov. Printer, Adelaide*: 315-600.

CROCKER, R. L., and COTTON, B. C., 1946. Some raised beaches of the lower south-east of South Australia and their significance. *Trans. Roy. Soc. S. Aust.* 70: 64-82.

FAUVEL, P., 1901. Les variations de la faune marine. *Feuilles des Jeun. Nat.* 363: 78-81; 364: 101-104.

FISCHER-PIETTE, E., 1935. Histoire d'une mouliere. Observations sur une phase de desequilibre faunique. *Bull. Biol. France et Belgique* 69: 153-177.

Fretter, Vera, and Graham, Alistair, 1962. British prosobranch molluscs, their functional anatomy and ecology. *London, Ray Soc.*: 1-755.

Gabriel, C. J., 1956. Mollusca from southeast of King Island, Bass Strait. *Mem. nat. Mus. Vict.* 22 (4): 1-16.

Gill, E. D., 1954. Australasian research on eustatic changes of sea-level. *Aust. J. Sci.* 16: 227-229.

————, 1956. Radiocarbon dating of Late Quaternary shorelines in Australia. *Quaternaria* 3: 133-138.

Gill, E. D., and Fairbridge, R. W., 1953. Research on eustatic sea-levels in Australia and New Zealand. *Rept ANZAAS Mtg* 29: 333-340.

Hedley, C., 1904. The effect of the Bassian isthmus upon the existing marine fauna: a study in ancient geography. *Proc. Linn. Soc. N.S.W.* 28: 876-83.

Hewatt, W. G., 1935. Ecological succession in the *Mytilus californianus* habitat as observed in Monterey Bay, California. *Ecology* 16: 244-251.

Hossfeld, P. S., 1950. The Late Cainozoic history of the southeast of South Australia. *Trans Roy. Soc. S. Aust.* 73: 232-279.

Howchin, Walter, 1923. The recent extinction of certain marine animals of the southern coast of Australia, together with other facts that are suggestive of a change in climate. *Rept. Aust. Assoc. Adv. Sci.* 16: 94-101.

Iredale, Tom, 1924. Results from Roy Bell's molluscan collections. *Proc. Linn. Soc. N.S.W.* 49: 179-278.

————, 1925. Mollusca from the continental shelf of eastern Australia. *Rec. Aust. Mus.* 14: 243-270.

Iredale, Tom, and May, W. L., 1916. Misnamed Tasmanian chitons. *Proc. Malac. Soc. London* 12: 94-117.

Iredale, Tom, and McMichael, D. F., 1962. A reference list of the marine Mollusca of New South Wales. *Aust. Mus. Mem.* 11: 1-109.

Jennings, J. N., 1959. The coastal geomorphology of King Island, Bass Strait, in relation to changes in the relative level of land and sea. *Rec. Queen Vic. Mus. Launceston* 11: 1-39.

Kendrick, G. W., and Wilson, B. R., 1959. *Anadara trapezia* (Mollusca: Pelecypoda) found living in south Western Australia. *West. Aust. Nat.* 6: 191-192.

Laseron, C. F., 1954. Revision of the New South Wales Turridae (Mollusca). *Roy. Zool. Soc. N.S.W.*: 1-56.

Macpherson, J. H., and Gabriel, C. J., 1962. Marine molluscs of Victoria. *Melbourne*: 1-475.

Mars, Paul, 1959. Les faunes malacologiques quaternaires "froides" de Mediteranee. Le gisement du Cap Creus. *Vie et Milieu* 9 (3): 293-309.

May, W. L., 1921. A check-list of the Mollusca of Tasmania. *Govt. Printer, Hobart*: 1-114.

————, revised by Macpherson, J. H., 1958. An illustrated index of Tasmanian shells. ibid.: 1-72.

Pelseneer, Paul, 1935. Essai d'Ethologie zoologique d'apres l'etude des Mollusques. *Acad. Roy. Belg. C. Sci. Publ. Found. Agathon de Potter* 1: 1-662.

Royal Netherlands Meteorological Institute, 1949. Seas around Australia. *Oceanogr. Meteorol. Data* 124.

Sprigg, R. C., 1952, The geology of the south-east province, South Australia, with special reference to Quaternary coast-line migrations and modern beach developments. *Geol. Surv. S. Aust. Bull.* 29: 1-120.

Sprigg, R. C., and Boutakoff, N., 1953. Summary report on the petroleum possibilities of the Gambier Sunklands. *S. Aust. Min. Rev.* 45: 41-62.

Valentine, J. W., 1963. Fossil bivalve gastropods from the Quaternary of western Victoria. *Aust. J. Sci.* 25: 467.

Vaux, D., and Olsen, A. M., 1961. Use of drift bottles in fisheries research. *Fish. Newsletter* 20 (1): 17-20.

Wilkins, R. W. T., 1962. *Miltha* in the south-eastern Australian Tertiary. *J. Malac. Soc. Aust.* 6: 43-49.

Womersley, H. B. S., and Edmonds, S. J., 1958. A general account of the intertidal ecology of South Australian coasts. *Aust. J. Mar. Freshw. Res.* 9: 217-260.

Explanation of Plates

Unless otherwise stated, the measurements given are for length (L), width (W), height (H), and diameter of the last whorl (D). Registration numbers are those of the National Museum of Victoria.

PLATE 3

Fig. 1—*Clavarizona hirtosa* Blainville. Bank St. Median valve, W 24·4 mm. P22984.
Fig. 2—*Notomella canidida* (A. Adams). Drain, unit A. L 10·6 mm, W 8·0 mm, H 1·5 mm. P22920.
Fig. 3—*Amblychilepas crucis* (Beddome). Drain, unit A. L 5·1 mm, W 3·3 mm, H 1·7 mm. P22921.
Fig. 4—*Amblychilepas oblonga* (Menke). Drain, unit C. L 7·8 mm, W 4·0 mm, H 1·7 mm. P22922.
Fig. 5—*Asteracmea crebristriata* (Verco). Drain, unit A. L 2·6 mm, W 1·0 mm, H 1·5 mm. P22924.
Fig. 6—*Asteracmea stowae* (Verco). Drain, unit A. L 3·6 mm, W 2·7 mm, H 0·9 mm. P22923.
Fig. 7—*Cantharidus kingensis* Gabriel. Drain, unit A. H 2·1 mm, D 1·5 mm. P22942.
Fig. 8—*Cantharidella tiberiana* (Crosse). Drain, unit A. H 2·6 mm, D 2·6 mm. P22932. Apex tilted slightly away from viewer.
Fig. 9—*Dolicrossea labiata* (Tenison Woods). Drain, unit A. H 2·2 mm, D 1·8 mm. P22980.
Fig. 10—*Munditia subquadrata* (Tenison Woods). Drain, unit A. H 2·3 mm, D 3·5 mm. P22935.
Fig. 11—*Minopa legrandi* (Petterd). Drain, unit A. H 1·6 mm, D 2·0 mm. P22927.
Fig. 12—*Minopa legrandi* (Petterd). Drain, unit A. H 1·7 mm, D 2·1 mm. P22928.
Fig. 13—*Minopa petterdi* (Crosse). Drain, unit A. H 1·9 mm, D 2·0 mm. P 22929.
Fig. 14—*Lodderia lodderae* (Petterd). Drain, unit A. H 1·2 mm, D 2·2 mm. P22934.
Fig. 15—*Elachonbis homalon* (Verco); a, apical view; b, umbilical view. Drain, unit A. H 0·9 mm, D 2·2 mm. P22933.
Fig. 16—*'Pellax' rosea* (Angas). Drain, unit A. H 9·3 mm, D 2·5 mm. P22949. Base less angulate and whorls more convex than usual.

PLATE 4

Fig. 1—*Charisma josephi* (Tenison Woods). Drain, unit A. H 1·9 mm, D 1·8 mm. P22969.
Fig. 2—*Pelecydium cylindraceus* (Tenison Woods). Drain, unit A. H 3·2 mm, D 1·2 mm. P22976.
Fig. 3—*Laevilittorina mariae* (Tenison Woods). Drain, unit A. H 2·7 mm, D 1·7 mm. P22943.
Fig. 4—*Pissina* cf. *P. frenchiensis* (Gatliff and Gabriel). Drain, unit A. H 2·5 mm, D 1·3 mm. P22939.
Fig. 5—*Pissina cf. P. frenchiensis* (Gatliff and Gabriel). Drain, unit B. H 2·6 mm, D 1·3 mm. P22938.
Fig. 6—*Bembicium nanum* (Lamarck). Juvenile; a apertural view; b, apical view. Drain, unit C. H 1·1 mm, D 3·1 mm. P22966.
Fig. 7—*Notosetia* cf. *N. atkinsoni* Tenison Woods. Drain, unit C. H 1.6 mm, D 1·1 mm. P22977.
Fig. 8—*Microdryas australiae* (Frauenfeld). Drain, unit A. H 2·5 mm, D 1·5 mm. P22947.
Fig. 9—*Lironoba tenisoni* (Tate). Drain, unit A. H 2·5 mm, D 1·2 mm. P22998.
Fig. 10—*Eatoniella melanchroma* (Tate). Drain, unit A. H 1·9 mm, D 1·2 mm. P22937.
Fig. 11—*Eatoniella* cf. *E. arantiocincta* (May). Drain, unit A. H 2·9 mm, D 1.6 mm. P22971.
Fig. 12—*Merelina hulliana* (Tate). Drain, unit A. H 3·2 mm, D 1·8 mm. P22944.
Fig. 13.—*Linemera filocincta* (Hedley and Petterd). Drain, unit A. H 2·6 mm, D 1·4 mm. P22945.
Fig. 14—*Rissolina angasi* (Pease). Drain, unit A. H 5·1 mm, D 2·2 mm. P22946.
Fig. 15—*Rissoina elegantula* Angas. Drain, unit A. H 5·1 mm, D 2·2 mm. P22936.
Fig. 16—*Tatea rufilabris* (A. Adams). Drain, unit C. H 3·7 mm, D 1·5 mm. P22968.
Fig. 17—*Cochliolepas vincentiana* (Angas). Drain, unit A. H 2·4 mm, incomplete, D 1·9 mm, incomplete. P22956.
Fig. 18—*Pseudoliotia micans* (A. Adams). Drain, unit A. Aperture and fragment of last whorl. Inside diameter of aperture 0·9 mm. P22981.

Fig. 19—*Diala semistriata* (Philippi). Drain, unit A. H 5·5 mm, D 2·4 mm. P22940.

Fig. 20—*Diala phasianella* Angas. Drain, unit A. H 4·5 mm—estimated (specimen broken), D 2·1 mm. P22941.

PLATE 5

Fig. 1—*Hypotrochus monachus* (Crosse & Fischer). Drain, unit A. H 2·3 mm, D 1·5 mm. P22957.

Fig. 2—*Notosinister angasi* (Crosse & Fischer). Drain, unit A. H (incomplete) 4·2 mm, D 1·3 mm. P22961.

Fig. 3—*Notosinister armillata* (Verco). Drain, unit A. H (incomplete) 3·2 mm, D 1·4 mm. P22965.

Fig. 4—*Notosinister ampulla* (Hedley). Drain, unit B. H 3·6 mm, D 1·4 mm. P22974.

Fig. 5—*Notosinister tasmanica* (Tenison Woods). Drain, unit A. H (incomplete) 6·1 mm, D 2·1 mm. P22979.

Fig. 6—*Notosinister maculosa* (Hedley). Drain, unit A. H 4·8 mm, D 1·8 mm, P22962.

Fig. 7—*Notosinister granulata* (Brazier). Drain, unit A. H 4·2 mm, D 1·3 mm. P22963.

Fig. 8—*Notosinister pfeifferi* (Crosse and Fischer). Drain, unit A. H 4·5 mm, D 1·5 mm. P22964.

Fig. 9—*Melanella* sp. A. Drain, unit A. H 4·2 mm, D 1·3 mm. P22972.

Fig. 10—*Macrozafra remoensis* (Gatliff & Gabriel). Drain, unit A. H 3·6 mm, D 1·6 mm. P22967.

Fig. 11—*Macrozafra* cf. *M. atkinsoni* (Tenison Woods). Drain, unit A. H 3·2 mm, D 1·2 mm. P22954.

Fig. 12—*Macrozafra* sp. A. Drain, unit A. H 3·6 mm, D 1·6 mm. P22955.

Fig. 13—*Zella* cf. *Z. beddomei* (Petterd). Drain, unit B. H 4·4 mm, D 2·0 mm. P22973.

Fig. 14—*Tavaniotha optata* (Gould). Drain, unit A. H 5·8 mm, D 3·5 mm. P22978.

Fig. 15—*Etrema densiplicata* (Dunker). Drain, unit A. H 4·2 mm, D 2·1 mm. P22982.

Fig. 16—*Euliginella shorehami* (Pritchard & Gatliff). Drain, unit A. H 1·8 mm, D 1·3 mm. P22975.

Fig. 17—*Cryptospira pygmaeoides* (Singleton). Bank St. H 5·6 mm, D 3·6 mm. P22983.

PLATE 6

Fig. 1—*Heterocithara bilineata* (Angas). Drain, unit A. H 4·6 mm, D 2·1 mm. P22950.

Fig. 2—*Guraleus vincentinus* (Crosse & Fischer). Drain, unit C. H 5·9 mm, D 2·8 mm. P22952.

Fig. 3—*Marita bella* (Adams & Angas). Drain, unit A. H 10·8 mm, D 3·9 mm. P22951.

Fig. 4—*Guraleus brazieri* (Angas). Drain, unit A. H 7·8 mm, D 2·7 mm. P22953.

Fig. 5—*Cylichnina pygmaea* (A. Adams). Drain, unit A. H 4·1 mm, greatest diameter 1·9 mm. P22930.

Fig. 6—*Retusa amphizosta* Watson. Drain, unit A. H (incomplete) 2·4 mm, greatest diameter 1·2 mm. P22931.

Fig. 7—*Agatha australis* (Angas). Drain, unit A. H 3·2 mm, D 1·3 mm. P22958.

Fig. 8—*Turbonilla beddomei* (Petterd). Drain, unit A. H 3·5 mm, D 1·2 mm. P22959.

Fig. 9—*Chemnitzia acicularis* (A. Adams). Bank St. H 6·9 mm, D 1·4 mm. P22960.

Fig. 10—*Edenttellina typica* Gatliff and Gabriel. Drain, unit A. Left valve, H 1·6 mm, L 2·2 mm. P22618.

Fig. 11—*'Berthelinia typica'* of Burn. Drain, unit A. Left valve, H 1·6 mm, L (incomplete) 1.7 mm. P22615.

Fig. 12—*Berthellinops serenitas* Burn. Bank St. L 7·4 mm, W 4·5 mm. P22970.

Fig. 13—*Siphonaria tasmanica* Tenison Woods. Drain, unit A. L 4·2 mm, W (incomplete) 3·2 mm, H 1·5 mm. P22925.

Fig. 14—*Mesembrisepia novaehollandiae* Hoyle. Bank St. W (incomplete) 16·2 mm. P22985.

PLATE 7

Fig. 1—*Pronucula hedley* Pritchard & Gatliff. Right valve. Drain, unit A. L 2·8 mm, H 2.4 mm. P22895.

Fig. 2—*Tucetilla striatularis* (Lamarck). Drain, unit C. L 12·5 mm, H 11·5 mm. P22896.

Fig. 3—*Lissarca rhombaidalis* Verco. Left valve. Drain, unit A. L 2·8 mm, H 2·3 mm. P22901.

Fig. 4—*Micromytilus crenatuliferus* (Tate). Left valve. Drain, unit A. L 2·3 mm, H 1·9 mm. P22904.

Fig. 5—*Brachidontes* cf. *B. rostratus* (Dunker). Right valve. Drain, unit A. L 2·9 mm, H 1·9 mm. P22909.

Fig. 6—*Lanistina paulucciae* (Crosse). Right valve. Drain, unit A. L 3·3 mm, H 2·1 mm. P22902.

Fig. 7—*Cylopecten favus* Hedley. Left valve. Drain, unit A. L 2·3 mm, H 2·1 mm. P22915.

Fig. 8—*Cuna delta* Tate & May. Right valve. Drain, unit A. L 2·0 mm, H 2·0 mm. P22898.

Fig. 9—*Cuna comma* Verco. Left valve. Drain, unit A. L 2·4 mm, H (incomplete) 3·3 mm. P22916.

Fig. 10—*'Cuna' planilirata* Gatliff & Gabriel. Right valve. Drain, unit A. L 1·8 mm, H 1·6 mm. P22918.

Fig. 11—*Cyamiomactra mactroides* (Tate & May). Right valve. Drain, unit A. L 2·1 mm, H 1·2 mm. P22910.

Fig. 12—*Neogaimardia rostellata* (Tate). Right valve. Drain, unit A. L 2·1 mm, H 1·8 mm. P22908.

Fig. 13—*Neogaimardia tasmanica* (Beddome). Right valve. Drain, unit A. L 1·9 mm, H 1·5 mm. P22903.

Fig. 14—*Marikellia* aff. *M. rotunda* (Deshayes). Right valve. Drain, unit A. L (incomplete) 3·9 mm, H (incomplete) 3·4 mm. P22891.

Fig. 15—*Marikellia* cf. *M. rotunda* (Deshayes). Right valve. Drain, unit A. L 3·5 mm, H 3·1 mm. P22890.

Fig. 16—*Notolepton sanguineum* Hutton. Right valve. Drain, unit C. L 2·0 mm, H 1·8 mm. P22917.

Fig. 17—*Notolepton antipodium* (Filhol). Left valve. Drain, unit A. L 2.3 mm, H 2·2 mm. P22905.

PLATE 8

Fig. 1—*Bassina* aff. *B. pachyphylla* (Jonas). Left valve. Drain, unit C. L 28·2 mm, H 21·4 mm. P22914.

Fig. 2—*Bornia trigonale* (Tate). Left valve. Drain, unit A. L 3·7 mm, W 3·0 mm. P22889.

Fig. 3—*Corbula coxi* Pilsbry. Left valve. Drain, unit A. L 7·0 mm, H 4·6 mm. P22897.

Fig. 4—*Thraciopsis elongata* (Stutchbury). Left valve. Drain, unit A. D 10·6 mm, H 4·6 mm. P22913.

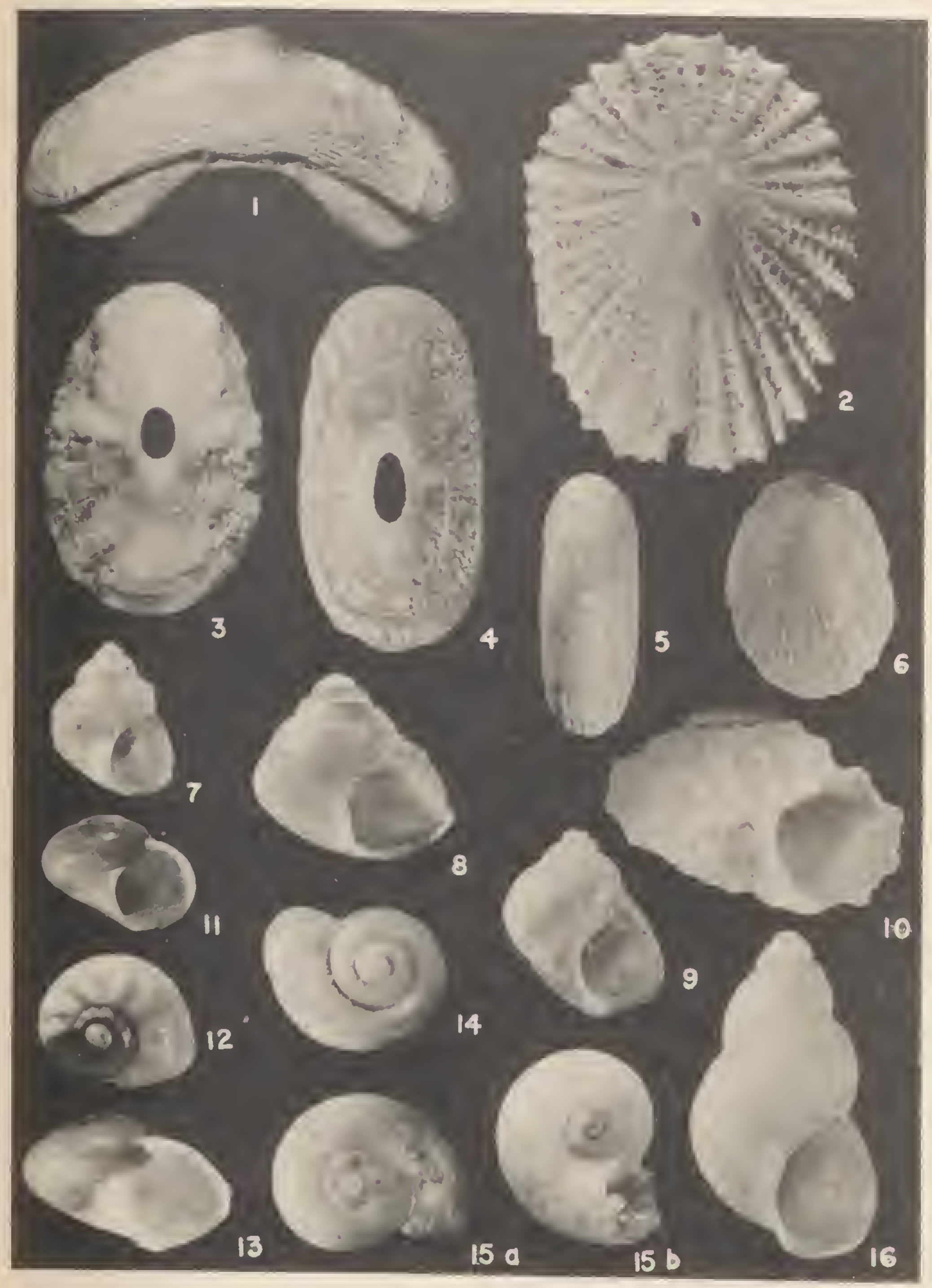
Fig. 5—*Mysella donaciformis* Angas. Right valve. Drain, unit A. L 5·2 mm, H 4·1 mm. P22907.

Fig. 6—*Semelangulus tenuiliratus* (Sowerby). Left valve. Drain, unit B. L 4·8 mm, H 2·6 mm. P22906.

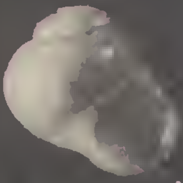
Fig. 7—*Myadora tasmanica* Tenison Woods. Right valve. Drain, unit A. L 4·9 mm, H (incomplete) 3·5 mm. P22912.

Fig. 8—*Ephippondonta lunata* (Tate). Left valve. Drain, unit A. L (incomplete) 3.4 mm, H (incomplete) 1·6 mm. P22894.

Fig. 9—*Lepton ovatum* Tate. Left valve. Drain, unit A. L 2·6 mm, H 1·8 mm. P22911.


1
2
3
4
5
6
7
8
10
11
9
14
12
13
15 a
15 b
16

PROC. ROY. SOC. VICT. 78 PLATE 4


1


2


3


4


5

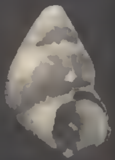

6 a


6 b


7


8


9


10


11


12


13


14


15


16


17


18


19


20

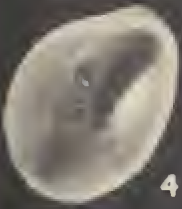

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17


1
2
3
4
5
6
7
8
9
10
11
12
13
14


1


2


3


4


5 a


5 b


6


7


8


9


10


11


12


13


14


15


16 a


16 b

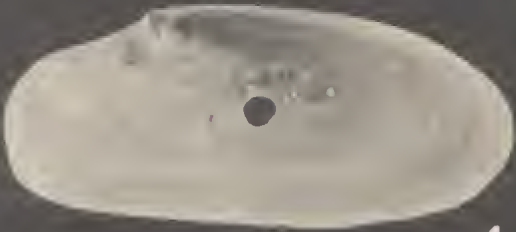

17 a


17 b

1

2

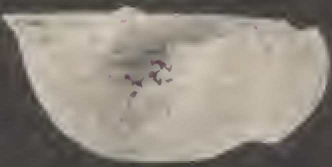
3



4

5

6



8

7

9

3

STRAIN-SLIP FOLIATIONS IN LOW-GRADE METAMORPHIC ROCKS, VICTORIA

By F. C. Beavis
Geology Department, University of Melbourne

Abstract

Strain-slip foliations due to deformations which preceded, were synchronous with, or post-dated advanced recrystallization were studied in phyllites and schists from Victorian metamorphic belts. Pre-recrystallization foliations are represented by domains of oriented mica; the geometry of the foliations is dependent on the number of deformations which took place before the re-crystallization. In the one example of pararecrystallization strain-slip foliation, the domains consist of closely spaced shear planes. The nature of post recrystallization strain-slip foliation depends on the rock involved: in phyllites they are kink zones and fine planar shears, in the crystalline schists they are narrow domains of mylonite. The geometry of these foliations is invariably discordant to that of pre-recrystallization foliations.

Introduction

Strain-slip cleavages in Ordovician sediments of C. Victoria were described recently (Beavis 1964a). This cleavage was restricted to pelitic rocks: in pure siltstones and slates it consisted of planar shears; in the interlaminated zones of complex oscillatory graded greywackes it was represented by conjugate first-order shears, or, more commonly, by conjugate second-order shears. No distinction could be made between shear cleavage and strain-slip cleavage. The study of strain-slip cleavage has now been extended to low-grade metamorphic rocks exposed in E. and W. Victoria.

Whereas, in C. Victoria, the strain-slip cleavage was imposed during the last phases of the main folding, and was more or less synchronous with the mild recrystallization of the sediments, examples of strain-slip foliations resulting from pre-, para-, and post-recrystallization deformation were recognized in the schists. This paper describes the strain-slip foliations observed; where practicable, microscopic fabric analyses supplement the mesoscopic and microscopic observations. Although the material was collected over a wide area, it is possible that some foliation styles may be present in the schists but were not noted.

Sincere thanks are due to Mr A. A. Baker who collected and made available some of the Orbost material, and to my wife for her painstaking care in the preparation of figures of specimens.

Prerecrystallization Strain-Slip Foliation

The schists of both NE. and SW. Victoria were developed by mimetic recrystallization of the deformed parent sediments (Tattam 1929, Wells 1956). In general, then, the foliations in these schists are an emphasis of deformation structures imposed before recrystallization. As many as four foliations have been noted.

An example from the Casterton schists, at Wando, shows intensely folded lithological layering, S, which represents the original bedding; an axial plane foliation S′; and two conjugate foliations S″, symmetrical about S′ ,formed during a late phase of the folding responsible for S′. Both S′ and S″ are restricted to pelitic layers and are marked by domains of biotite flakes (Fig. 1). S′ clearly represents original slaty cleavage, and S'' original conjugate strain-slip cleavage. It was noted that one set of S'' (S''_a) was more prominent than the other (S''_b), S''_b frequently being visible only microscopically.

Wells (op. cit.) recorded boudinage in psammitic beds of the Casterton schists. The conjugate strain-slip cleavage has disrupted fine psammitic laminae to form microboudins (Fig. 2a). Conjugate S'' and microboudins occur only in the altered

Fig. 1—Foliations in biotite schists, Wando.

schists which were originally interlaminated zones of oscillatory graded beds. In S′ and S″ the biotite flakes normally lie with {001} parallel to the S plane defined by the biotite. In some cases, however, {001} makes an angle with S″; this may be a second-order effect (Fig. 2b). Microscopic analysis of the biotite subfabric (Fig. 2c) emphasizes the dominance of S′; the point maximum for {001} biotite is normal to this foliation. S″ are not clearly defined on the diagram, but the orientation of biotites in these foliations is reflected in the spread about the point maximum.

Although the quartz grains show no obvious dimensional orientation, the in-

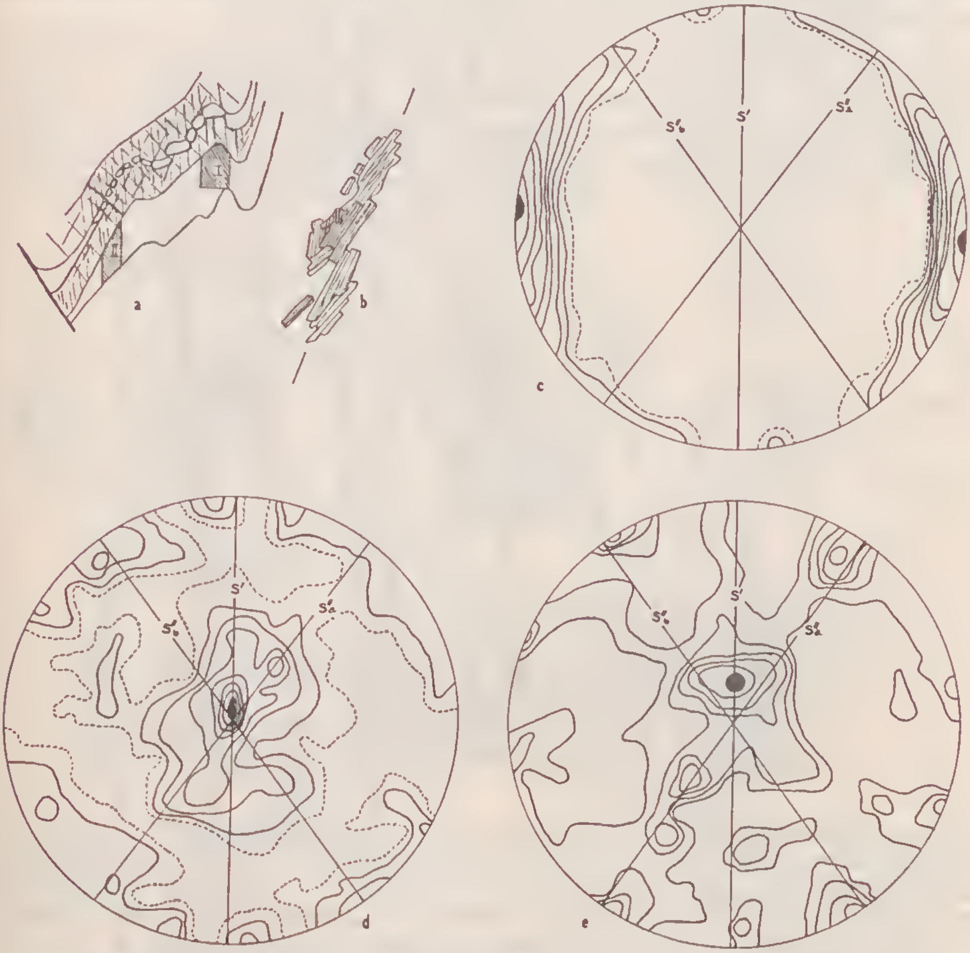


FIG. 2—Microscopic analysis of Casterton Schist.

a. Microboudins in psammitic lamina.
b. Biotite flakes lying in S″.
c. 200 {001} biotite. Contours ½-1-2-4-5-8-10-14-16%.
d. 200 [0001] quartz on hinge of small fold; subarea 1 of Fig. 2a. Contours ½-1-2-3-4-5-6-7%.
e. 200 [0001] quartz on limb of small fold; subarea 11 of Fig. 2a. Contours 1-2-3-4-6-8%.

fluence on the [0001] quartz subfabric of S′ and S″ is clearly seen in Fig. 2d and 2e. Tests on both subareas analyzed showed a high degree of homogeneity in the [0001] quartz; in both subareas [0001] lies in the foliations, a result noted in schists from S. of Beechworth (Beavis 1964b). The high concentrations of [0001] lie close to the axis B defined by the intersection of S′ S''_a and S''_b. In Fig. 2e, the greater strength of the girdle S''_a reflects both the prominence of this plane over S''_b and the orienting influence of S. This subfabric has triclinic symmetry.

Both the biotite and quartz fabrics were inherited; there is no evidence of deformation of either quartz or biotite, and the small quartz and mica crystals of the parent sediment formed oriented nuclei during the recrystallization.

Biotite schists at Tawonga, in NE. Victoria, have only two apparent foliations: a a folded lithological layering S and an axial plane foliation S″, which may be a fracture cleavage. The constituent minerals are not deformed. The small folds in S have a chevron style; the axial plane foliation associated with these folds is not truly penetrative, but is restricted to the hinges of the small folds. In these domains {001} biotite is still parallel to S. Here, fracture cleavage was imposed before recrystallization.

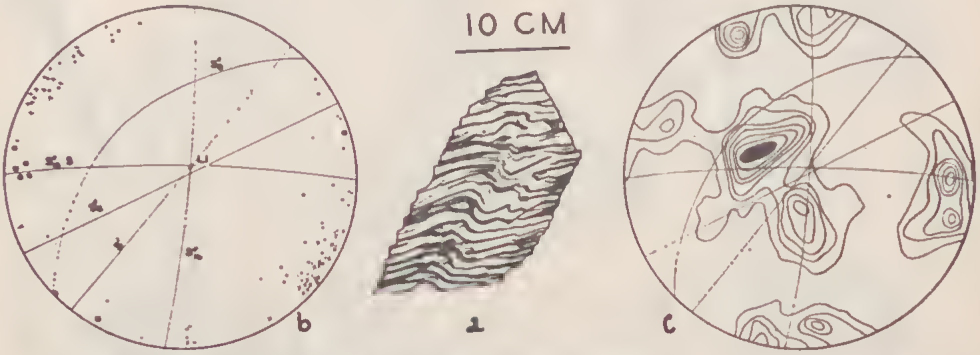


FIG. 3—Quartz biotite schist, Princes Highway, Orbost.
- a. Foliations in schist.
- b. Crosses indicate poles to {001} of biotite lying in S and dots, poles {001} of biotite lying in S''_a. Circled points are biotites which have suffered post-recrystallization deformation.
- c. 200 [0001] quartz. Contours 1-2-3-4-5-6-8%. Foliations and lineations shown on b and c are those visible on the small specimen from which thin sections were cut.

A quartz-biotite schist from Orbost is of particular interest in that it suffered two unrelated deformations before recrystallization; this is evidence of a postrecrystallization deformation also. The mesoscopic geometry is treated only superficially here; more detailed work has yet to be completed. The most prominent foliation is the lithological layering, S, and the least prominent, mesoscopically, is the axial plane foliation S′, of the first folding. This latter foliation, however, is microscopically dominant. A late phase of the first deformation imposed a conjugate strain-slip cleavage, S''_1. S has been folded into small chevron-style folds, the hinges of which form the strong lineation L_1. S''_1 is parallel to S, S''_{1b} cuts S''_{1a} almost at right angles. The second deformation involved the superposition of a strain-slip cleavage S''_2 which deformed the earlier planar and linear structures;

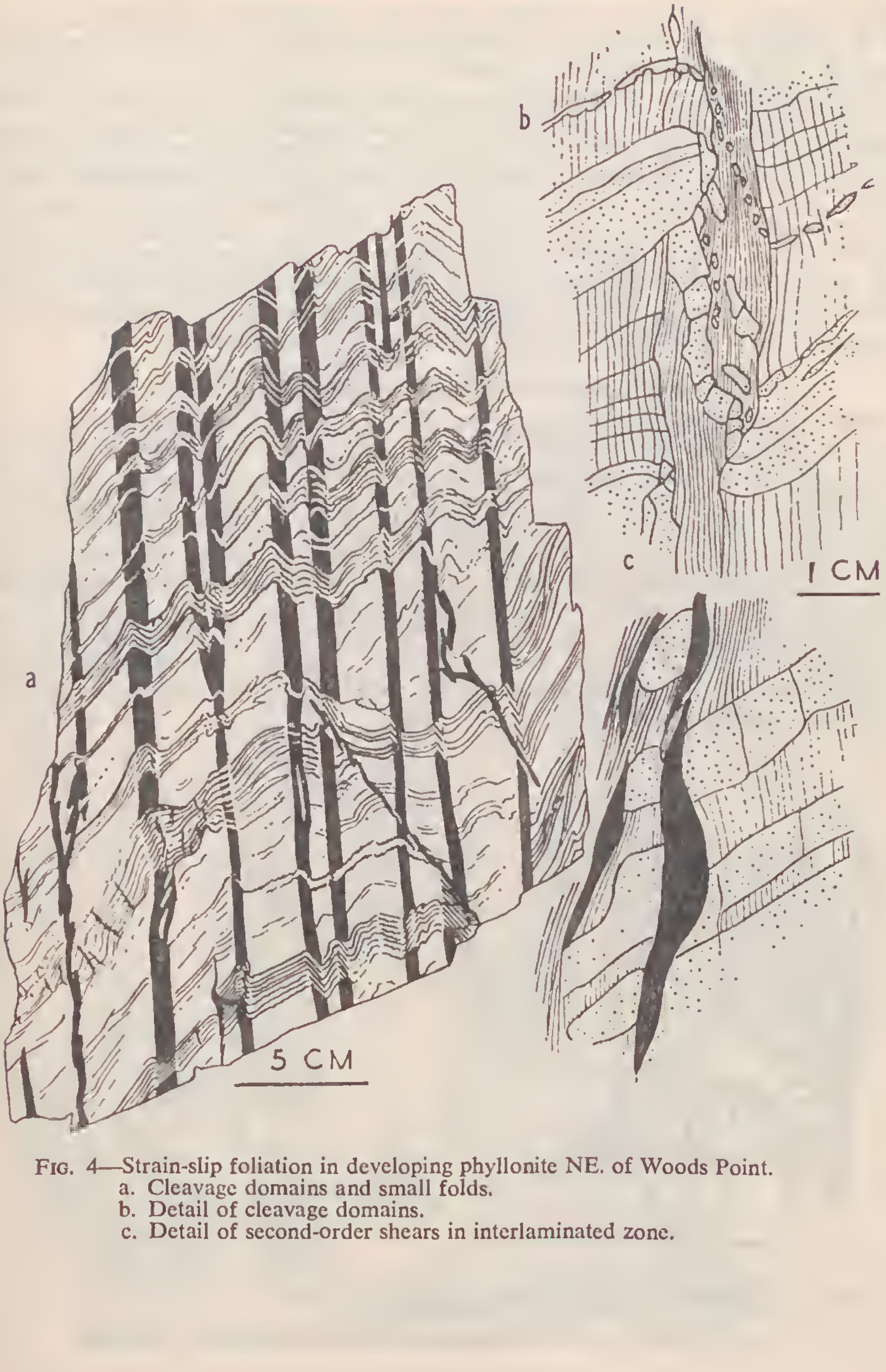


FIG. 4—Strain-slip foliation in developing phyllonite NE. of Woods Point.
a. Cleavage domains and small folds.
b. Detail of cleavage domains.
c. Detail of second-order shears in interlaminated zone.

transposion of S on S''_2 is particularly obvious. A post-recrystallization deformation is suggested by a series of relatively widely spaced parallel discrete shear planes, S''_3. Fig. 4a shows S, S′, S''_{1b} and S''_2.

Microscopic analysis of the biotite and quartz subfabric is shown in Fig. 3b and 3c. Fig. 3b shows that {001} biotite is statistically parallel to S′, irrespective of the foliation in which the biotite lies; S''_3 has had some influence on the biotite subfabric and those biotite flakes parallel to this surface show deformation characteristics. This is a contrast with other biotite subfabrics examined during the present work; {001} biotite was parallel, or nearly so, to the foliation in which it lies. The quartz has a strong dimensional orientation, the plane containing the maximum and intermediate dimensional axes lying parallel to S′. The [0001] quartz fabric which, like the biotite fabric, has triclinic symmetry, has no apparent relationship to the planar and linear structures observed mesoscopically.

Pararecrystallization Strain-Slip Foliation

Strain-slip foliation developed during recrystallization was noted in one area only—on the margin of a phyllonite-mylonite belt NE. of Woods Point. The rarity of this class of strain-slip foliation is not unexpected; during recrystallization the condition of the rock would tend to militate against shear cleavage development. In the Woods Point phyllite, the strain-slip foliation is marked by domains of shearing up to 1 cm thick. Although the domains, apparently, are sharply bounded, microscopic examination shows that this is not so. Midway between any two domains single shear planes are spaced at intervals of 0·2-0·4 mm. As the domains are approached, the spacing decreases, until, within the domains, individual shear planes are spaced at 0·01 mm or less. The cleavage domains, then, are made up of large numbers (1000±) of shear planes; the displacement on the domains is the sum of the small displacements on each plane.

FIG. 5—Strain-slip cleavage in schists, Beechworth.
a. Cleavage domains and microcoulisse folds.
b. 200 [0001] quartz from microcoulisse fold. Contours 1-2-3-4-5-6%.

Where the domains cross interlaminated thin siltstones and phyllite, second-order shears have been induced (Fig. 4b). Across these zones, the first-order shears are curved, and are refracted at the boundaries. In quartzite laminae, the cleavage planes anastomose; for a cleavage plane to actually cross a quartzite lamina, however, is very rare, and the microfolding of these laminae was usually by flexure. Deformation of the phyllite can be visualized as laminar flow with very closely spaced flow planes. Thus, within the shear domains at least, the developing phyllite

FIG. 6—Conjugate strain-slip cleavage in phyllite, Mt St Bernard.

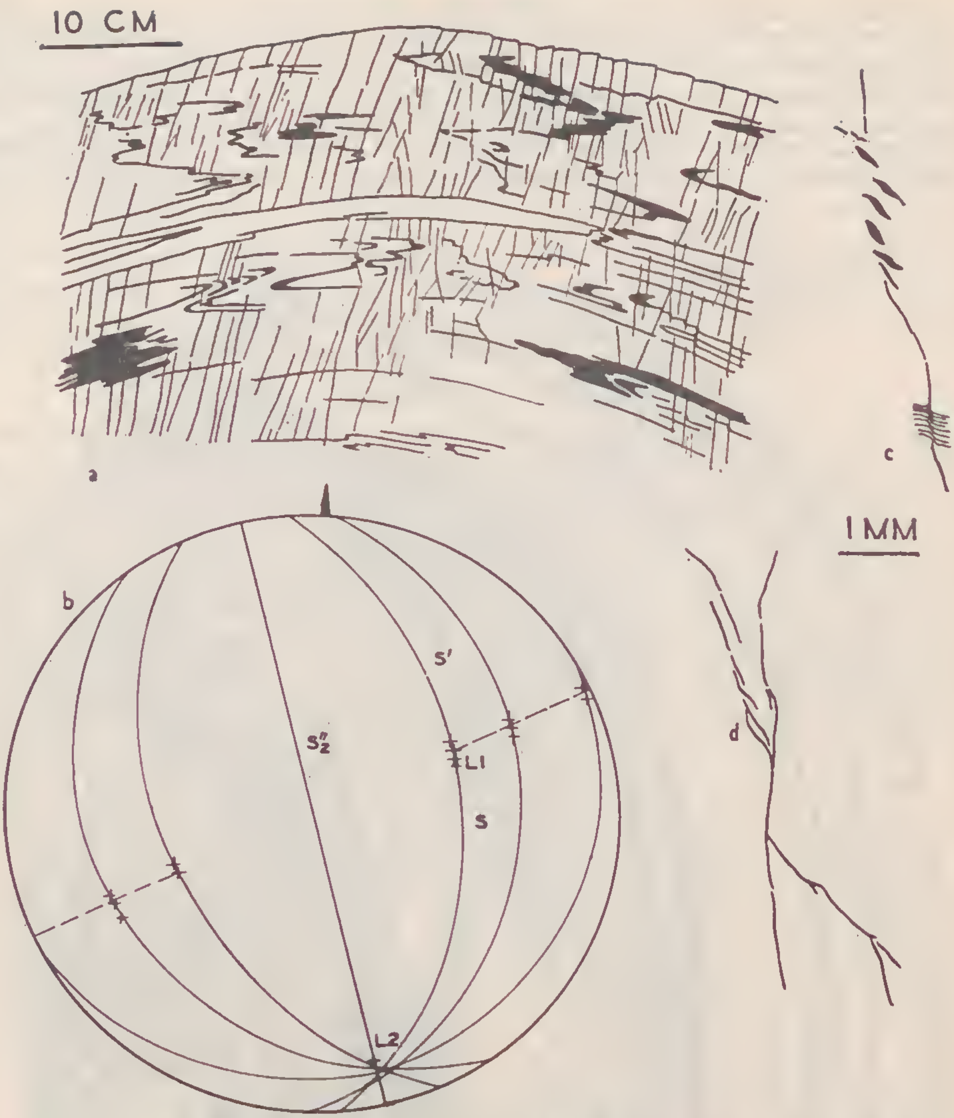


FIG. 7—Strain-slip cleavage in phyllite, Mt Feathertop.

- a. Profile of part of a second-generation fold showing smaller folds of the first generation, original bedding, and first-generation axial plane cleavage deformed by S″.
- b. Geometry of fold of Fig. 8a.
- c. Second-order shears in S″.
- d. Kinks and conjugate strain-slip cleavage.

was in a condition approaching viscous; the quartzites, however, remained competent (Fig. 4c). Any clear disruption of quartzite by cleavage planes seems to have been restricted to laminae less than 0·2 mm thick.

Post-recrystallization Strain-Slip Foliation

Superposed folding, during which this foliation was induced in schists and phyllites, appears to have occurred on a regional scale in the Mitta Mitta, Beechworth, and Upper Ovens Valley areas. Locally, in the Tawonga-Mt Hotham and Beechworth areas, very intense strain-slip cleavage and superposed folding is also associated with major faults.

An example of strain-slip cleavage, formed during fault movement, from near Beechworth, is illustrated by Fig. 5a. The rock is a layered quartz-biotite schist, the layers representing original bedding lamination (S). The strain-slip cleavage (S″) has deformed S, with the formation of **microcoulisse** folds, domains of shearing forming the fold limbs. The cleavage domains, 0·5-3·5 mm thick, consist of finely crushed mica and microlenses of quartz, the texture frequently approaching mylonite. Although not prominent, there is a second conjugate set of cleavage cutting across the fold limbs.

Microscopic analysis of the quartz subfacric (Fig. 5b) of the **microcoulisse** folds shows that the symmetry of this sub-fabric is triclinic. [0001] quartz lies in girdles coincident with the conjugate S″ and with S planes of an earlier deformation. The strong point maximum lies in the lineation defined by the intersection of the stronger S″ (S''_a) and S′ of the prerecrystallization deformation.

In the area W. of the West Kiewa Thrust (Beavis 1962) phyllites have had strain-slip cleavage superposed by the stresses responsible for the fault movement. At Mt St Bernard, the cleavage forms two irregular sets (Fig. 6); the only other foliations are the original bedding and, locally, a very weak axial plane cleavage of the first (Benambran) folding. The strain-slip cleavage here consists of fine shear planes; the folding on the cleavage is very fine, and usually has a conjugate style.

Closer to the thrust, the strain-slip cleavage in the phyllites is more intense, and movement along the cleavage has superposed relatively large (10 cm-1 metre) folds on the previously folded rocks. A profile of part of one of these superposed folds is shown in Fig. 7a and the geometry of the fold on Fig 7b. There is considerable variation in both the style of the strain-slip cleavage and in the nature of the cleavage domains. Incipient cleavage is marked by slight kinking of the earlier foliations (Fig. 7d); this passes along the domains into distinct shear fractures. Although the effects of lithological changes are slight, they were sufficient for second-order shears (Fig. 7c) to develop in the layers of less fine material. Two conjugate sets of cleavage may occur locally (Fig. 7d). This style is frequent enough to be significant. In this area, further work is under way since at least three deformations are known to have occurred.

Discussion

Irrespective of the time relationships of recrystallization and deformation, the style of the strain-slip cleavage appears to depend on the nature of the rock involved. Thus, second-order shears are found only in fine textured phyllites and schists; they are not found in the finest textured rocks, nor in the coarser crystalline schists. Conjugate cleavage also shows some restriction but this is not as well defined as that of the second-order shears. In any case, conjugate srain-slip cleavage appears far more frequently than was anticipated. While the actual nature of the cleavage domains, too, depend to a large extent on lithology, this is controlled more by the time relationship between deformation and recrystallization.

The geometrical relationship of the strain-slip cleavage depends on whether this cleavage was imposed by deformations responsible for other foliations, or whether it was the result of unrelated deformations. In most Victorian schists, the pre-recrystallization strain-slip cleavage is either an axial plane foliation at the large folds, or is symmetrically related to the axial planes. These foliations were obviously imprinted at a late phase of the deformation responsible for the main folding. Recrystallization has given a mimetic emphasis to the cleavages, which appear in the schists as strong foliations. Both biotite and quartz subfabrics of these schists have an intimate relationship with the mesoscopic fabric. The Orbost material is an exception, and further work will be required here.

Pararecrystallization strain-slip cleavage is rare, and it is impossible to generalize from one set of examples. In these examples, movement of incompetent rock apparently occurred by laminar flow within the cleavage domains.

As would be expected, there is a geometric discordance between pre-recrystallization and post-recrystallization foliations; any accordance would be fortuitous. In the post-recrystallization strain-slip cleavage, the nature of the domains is controlled by lithology. The coarser crystalline schists have domains with a mylonite texture, and it seems probable that movement occurred by flow in the domains. In phyllites and finely crystalline schists, the cleavages tend to be more or less discrete shear planes.

References

BEAVIS, F. C., 1962. The geology of the Kiewa Area. *Proc. Roy. Soc. Vict.* 75: 349-410.

————, 1963. Superposed folds in the metamorphic complex, North East Victoria. *Aust. J. Sci.* 26: 23.

————, 1964a. Strain slip cleavage in Ordovician sediments, Central Victoria. *Geol. Mag.*

————, 1964b. Superposed folding in the Beechworth contact aureole. *Proc. Roy. Soc. Vict.* 77: 265-272.

TATTAM, C. M., 1929. The metamorphic rocks of North East Victoria. *Bull. Geol. Surv. Vict.* 52.

WELLS, B. E., 1956. Geology of the Casterton District. *Proc. Roy. Soc. Vict.* 68: 85-110.

4

CRETACEOUS AND TERTIARY MICROPLANKTON FROM SOUTH-EASTERN AUSTRALIA

By Isabel C. Cookson
Botany Department, University of Melbourne

Abstract

One new genus and 4 new species of microplankton are described from Upper Eocene sediments in Victoria. A new Upper Cretaceous species is described and 2 Victorian Upper Cretaceous records included.

Introduction

The present paper is mainly concerned with a few of the many types of microplankton that occur in the sequence of Upper Eocene deposits situated at Brown's Ck in the Aire District, SW. Victoria (Carter 1958). The samples studied are representative of the Brown's Creek Clays (Carter loc. cit.), a carbonaceous clay, Greensand, a calcareous clay 15 ft above the Greensand, and a gritty clay 40-50 ft above the Greensand.

In addition, the occurrence is recorded of 3 microplankton types in Victorian Upper Cretaceous deposits, one of which had been known previously only from the Northern Hemisphere (Wetzel 1961, Gorka 1963, Manum & Cookson 1954). All 3 came from samples made available by Frome Broken Hill Co. from bores sunk in SW. Victoria. One of the Cretaceous types also occurs in a core-sample at 327 ft from SANTOS Oodnadatta Bore, South Australia provided by Dr R. C. Sprigg of Adelaide.

The holotypes and hypotypes are in the palaeontological collection of the National Museum of Victoria. Numbers prefaced by the letter P are registered numbers in that collection.

Systematic Descriptions

Class Dinophyceae

Family Hystrichosphaeridiaceae Evitt

Genus **Diphyes** n.gen.

Description: Shell composed of two parts, more or less unequal in size. The anterior part circular in outline with or without appendages. Archeopyle apical. The posterior part roughly bell-shaped to spherical with a small circular antapical opening and without typical appendages.

Type Species: *Diphyes colligerum* (Deflandre & Cookson)

Comment: This genus ,while having a hystrichosphaeridoid appearance, differs from other genera in the Hystrichosphaeridiaceae in its constantly bipartite form. Whether or not these two parts communicate cannot be proved beyond doubt. In a few specimens mounted in an anteroposterior position it has been possible to focus from one cavity to the other without any apparent obstruction to the view (Pl. 9, fig. 5, 6) so that if a dividing wall does exist, as was stated in the original description of the type species (Deflandre & Cookson 1955), it must be a very thin one. Sections are the only solution to this morphological problem.

Diphyes colligerum (Deflandre & Cookson)

(Pl. 9, fig. 1-12; hypotypes fig. 1, 2, P23029-23030)

non *Hystrichosphaeridium* sp. *c* Cookson 1953, Pl. 2, fig. 29, 30.
Hystrichosphaeridium colligerum Deflandre & Cookson 1955, p. 178. Pl. 7, fig. 3. Holotype P16301.
Baltisphaeridium colligerum (Deflandre & Cookson) Downie & Sarjeant 1963, p. 91.

AGE AND OCCURRENCE: Probably Senonian: Frome Broken Hill Co. Eumeralla No. 1 Bore, SW. Vict. between 3050 and 3060 ft. Eocene: type locality Princetown member of Dilwyn Clay, Cape Ronald, SW. Vict. 5 ft above beach level; Rottnest Bore, W.A. between 1480 and 1541 ft (Cookson & Eisenack 1961); new locality Upper Eocene Brown's Ck, SW. Vict. Greensand and deposit 15 ft above the Greensand.

EMENDED DESCRIPTION: Anterior portion of shell almost spherical, dorsoventral, with numerous broadly-based, stiff or flexuous, usually unbranched tubular appendages of varying lengths and widths that narrow towards small bluntly-pointed, capitate or somewhat funnel-shaped apices. On one surface, taken as ventral, some of the appendages are arranged in two short longitudinal rows one on either side of the mid-line (Pl. 9, fig. 1, 3); on the dorsal surface they are evenly distributed (Pl. 9, fig. 2, 4); an archeopyle occupies a large part of the apex (Pl. 9, fig. 5). The appendages are hollow at and near their bases and, contrary to the statement of Deflandre & Cookson (1955), their cavities appear to communicate with that of the shell (Pl. 9, fig. 10). However, it is practically impossible to prove this point, as well as to trace the cavity along the whole length of the longer appendages owing to the narrowness of their distal portions and the relative thickness of their walls. The wall of the anterior portion of the shell, *c.* 1·5 μ thick, is two-layered. The outer layer is densely granular in surface view the granules appearing as minute rods in optical section under oil immersion; similar rods are frequently evident on the walls of the appendages.

Posterior portion of the shell usually smaller and thinner-walled than the anterior portion, roughly bell-shaped with straight or convex sides and, in well-preserved specimens, a centrally-placed, cone-like projection with a small circular opening (Pl. 9, fig. 12). The surface is devoid of appendages, apart from one or two circles of small, knob or spine-like thickenings in the vicinity of the antapical opening (Pl. 9, fig. 7, 8, 11). The wall, *c.* 1 μ thick, is smooth in optical section, finely granular in surface view, the granules being arranged in more or less clearly defined longitudinal rows (Pl. 9, fig. 1).

DIMENSIONS: Hypotypes—(Pl. 9, fig. 2) overall length of shell 55 μ, width of anterior part 31 μ, width of posterior part *c.* 26 μ; (Pl. 9, fig. 3) overall length of shell 57μ ,width of anterior part *c.* 33 μ, width of posterior part 26 μ. Range—overall length 36-57 μ; width, anterior part 29-36 μ, posterior part 13-26 μ; appendages 5-21 μ long.

COMMENT: The recovery of a single specimen of *D. colligerum* (Pl. 9, fig. 4) from cuttings taken from Frome Broken Hill Co. Eumeralla No. 1 Bore between 3050 and 3060 ft requires special consideration. The deposit at this level, in containing several types of Dinoflagellates, e.g. *Deflandrea thomasi* Cookson & Eisenack and *D. belfastensis* Cookson & Eisenack (1961), which occur in other Upper

Cretaceous deposits in SW. Victoria, is undoubtedly of Upper Cretaceous age, Senonian or younger. This occurrence suggests that the time-range of *D. colligerum* may have been from high in the Upper Cretaceous to Upper Eocene. Since the residue in which this specimen occurred came from cuttings, additional examples from Upper Cretaceous deposits will be needed to establish such a range.

The reference of the Tertiary form *Hystrichophaeridium* sp. *c* Cookson 1953 to *Hystrichosphaeridium colligerum* by Deflandre & Cookson is herein disallowed following a re-examination of the figured specimen. This specimen shows no sign of the bipartite shell typical of the new genus *Diphyes* and its type species *D. colligerum*. Occasional specimens of *D. colligerum* in which the posterior part is exceptionally narrow (*c*. 13 μ) and straight-sided, bear a superficial resemblance to some examples of the genus *Coronifera* Cookson & Eisenack 1958.

Diphyes nudum n. sp.

(Pl. 10, fig. 1-4; holotype fig. 1, P23031; paratype fig. 4, P23032)

Age and Occurrence: Upper Eocene: Brown's Creek Greensand, SW. Victoria.

Description: Both parts of the shell without appendages. Anterior portion slightly larger than posterior portion, almost spherical with a large apical archeopyle. Wall *c*. 2 μ thick, smooth in profile, faintly dotted to finely granular in surface view.

Posterior portion slightly smaller than the anterior portion with convex sides and a slight apical prominence with a small opening; wall *c*. 1 μ thick, smooth in profile, faintly dotted or finely granular in surface view the granules when developed being arranged in regular longitudinal rows as in *D. colligerum* (Pl. 10, fig. 3, 4).

Dimensions: Holotype—overall length 55 μ, anterior part 35 μ wide, posterior part 32 μ wide. Range—overall length 47-65 μ ,width of anterior part 31-42 μ, width of posterior part 26-36 μ.

Comment: Although only 12 specimens of *D. nudum* have been found, the complete absence of appendages from the anterior portion of the shell seems sufficiently constant to justify specific distinction.

Genus **Hystrichosphaeridium** Deflandre

Hystrichosphaeridium ellipticum n. sp.

(Pl. 11, fig. 1-3a; holotype fig. 1, P23033; paratype fig. 2, P23095)

Age and Occurrence: Upper Eocene: Brown's Ck Greensand, calcareous clay 15 ft above Greensand.

Description: Shell elliptical in outline, untabulated, thin-walled with about 30-45 hollow appendages of varying lengths and widths which tend to be more numerous in the vicinity of apex and antapex (Pl. 11, fig. 2, 3). Archeopyle apical with a truncate edge. Appendages simple or branched, unequal in size, narrowing distally from base to broaden again apically; apices funnel-shaped, varying considerably in both width and depth, rims fringed with fine, branched processes the ultimate branchlets frequently visible only under oil immersion (Pl. 11, fig. 3a); cavities of appendages traceable to the main processes fringing the rims (Pl. 11, fig. 3a). Shell-membrane *c*. 0·5 μ or less thick, two-layered, outer layer smooth in optical section, finely and closely granular in surface view, sometimes more conspicuously so near the bases of the appendages especially at the antapex.

DIMENSIONS: Holotype—overall length *c.* 187 μ, overall width *c.* 109 μ; shell 101 × 52 μ. Range—three open shells, length 83 μ, width 47-52 μ; appendages 21-39 μ long.

COMMENT: A close affinity is evident between *H. ellipticum* and *H. paradoxum* Brosius 1963 from certain German mid-Oligocene deposits. Both have elongate-oval shells and funnel-shaped appendages of varying lengths and widths. However, judging by the illustrations of Brosius, the number of appendages in *H. paradoxum* (unfortunately not specified in the text) is considerably lower than that in *H. ellipticum*. Moreover, the long 'flagelliform' processes bordering the rims of the appendages (Brosius loc. cit. Abb 2) are shown as unbranched in contrast to the secondary and tertiary branchlets of *H. ellipticum*. In addition, the dimensions of open shells of *H. ellipticum* considerably exceed those given for *H. paradoxum*.

Family AREOLIGERACEAE Evitt

Genus **Cyclonephelium** Deflandre & Cookson emended Cookson & Eisenack 1962

Cyclonephelium retiintextum n. sp.

(Pl. 11, fig. 4; holotype, P23094)

AGE AND OCCURRENCE: Upper Cretaceous: Senonian or younger, Frome Broken Hill Co. Eumeralla No. 1 Bore, cuttings taken between 3090 and 3100 ft, and 3110 and 3120 ft.

DESCRIPTION: Shell oval with a small, median, blunt apical projection; archeopyle apical. Ornament in the form of an open-meshed network formed by the distal anastomosis of simple or more commonly slender branched processes of variable widths (*c.* 0·5μ-5μ) which arise well within the margin of the shell (*c.* 15-21μ); sometimes the bases of adjacent processes are connected by straight or curved strands. The distal branches delimiting the meshes are occasionally somewhat flattened and slightly perforated. The unornamented central portions of both dorsal and ventral surfaces are relatively small (*c.* 42 μ wide in the holotype). The shell membrane is two-layered, thin (*c.* 1 μ) and finely granular.

DIMENSIONS: Holotype—overall length 177μ, overall width 117μ, shell 94 × 78μ, appendages 20-30 μ long.

COMMENT: Only 2 specimens have been found. The unfigured paratype (P23097) is open apically but otherwise agrees with the holotype.

Of the described species of *Cyclonephelium* the one to which *C. retiintextum* approaches at all closely is *C. reticulosum* Gerlach (1961) from an Upper Oligocene deposit in NW. Germany. In this species, it is evident from the description and figure that the processes forming the network are situated close to the margin of the shell and that, in consequence, the greater part of both dorsal and ventral surfaces are unornamented. This arrangement clearly contrasts with the more central position of the network and the consequent smaller size of the unornamented surfaces of *C. retiintextum*. In addition, the distal finely reticulate bands associated with the reticulum of *C. reticulosum* have not been observed in *C. retiintextum*.

Family Uncertain

Genus **Horologinella** Cookson & Eisenack

Horologinella incurvata Cookson & Eisenack

(Pl. 10, fig. 13)

Horologinella incurvata Cookson & Eisenack 1962, p. 272, Pl. 37, fig. 5.

COMMENT: A few specimens identical with the type and other specimens from Eocene deposits in the Rottnest Is. Bore, Western Australia between 1285 and 1385 ft, and 1480 and 1541 ft have been observed in preparations of the Greensand and clay 15 ft above Greensand from Brown's Ck, SW. Victoria. An opening has not been evident.

Horologinella? spinosa n. sp.

(Pl. 10, fig. 10-12; Pl. 11, fig. 10; holotype fig. 11, P23036; paratypes fig. 12, P23037, Pl. 11, fig. 10, P23096)

OCCURRENCE: Upper Eocene: Brown's Ck, SW. Victoria. Carbonaceous clay, Greensand, calcareous clay 15 ft above Greensand, and gritty clay 40-50 ft above Greensand.

DESCRIPTION: Cyst without fields, with deeply concave sides and straight to slightly concave ends (cf. *H. incurvata* Pl. 11, fig. 13). Wall *c.* 0·5-1μ, thick mainly smooth, except at the distal rounded ends of the 4 arms where it is ornamented with small, solid, spine-like projections. One of the arms at the 'anterior' end is slightly longer than the other 3 and sometimes narrows slightly towards the apex. In 2 examples (cf. Pl. 11, fig. 10) the apex of the longer arm is open, apparently as the result of a natural transverse break.

DIMENSIONS: Holotype—*c.* 42 μ long, 39 μ broad. Range—*c.* 23-42 μ long, *c.* 23-39μ broad.

COMMENT: This form is doubtfully referred to *Horologinella* on account of its resemblance to the capsule of *Halophoridia xena* Cookson & Eisenack 1962, especially as regards the greater prominence and narrower shape of one of the 'anterior' arms. However, in *H. xena* the capsule is enclosed in a hyaline membrane whereas, in the 10 specimens of *Horologinella? spinosa* seen, no trace of such a membrane has been present.

H.? spinosa differs from the cysts of the described species of *Horologinella* Cookson & Eisenack 1962 and the capsules of *Halophoridia xena* in the development of spines at and adjacent to the apices of the 4 arms. In 3 specimens (Pl. 10, fig. 10) minute dot-like thickenings are scattered over the general surface; in the holotype (Pl. 10, fig. 11) 2 groups of dots are present, one at each end of the 'waist'-like region.

INCERTAE SEDIS

ACRITARCHA Evitt

Subgroup ACANTHOMORPHITAE Downie, Evitt, & Sarjeant

Genus **Baltisphaeridium** Eisenack

Baltisphaeridium nanum n. sp.

(Pl. 10, fig. 5-8; holotype fig. 5, P23034; paratype fig. 9, P23035)

AGE AND OCCURRENCE: Upper Eocene: Brown's Ck, SW. Victoria carbonaceous clay, Greensand, calcareous clay 15 ft above Greensand, and gritty clay 40-50 ft above Greensand.

DESCRIPTION: Shell small, usually circular in outline, densely covered with short, unbranched, hair-like appendages with slightly broadened bases, the lengths of which are about ¼-⅓th of the diameter of the shell. Opening *c.* 2 μ, roundish in outline.

DIMENSIONS: Holotype—overall diameter 44 μ, diameter of shell 33 μ; appendages *c.* 5 μ. Range—overall diameter *c.* 36-55 μ, diameter of shell *c.* 23-34 μ; appendages *c.* 5-13 μ long.

COMMENT: *B. nanum* is a regular, though not frequent component of the microplankton assemblages contained in the 4 deposits from Brown's Ck mentioned above. It seems to be distinguishable from all the well-illustrated species of *Baltisphaeridium* in the combination of small shell-size and large number of short hair-like appendages. The species to which *B. nanum* is most closely similar is *B. whitei* (Deflandre & Courteville 1939) originally described from French Senonian flints but the shells of this form are consistently larger, 56-60 μ, and the 'filaments' longer, up to about 28 μ, than those of *B. nanum*. In two examples of the latter, the shell seems to narrow slightly and the appendages to be fewer at this point (Pl. 10, fig. 7, 8), an appearance that could be related to the small opening occasionally seen in surface views (Pl. 10, fig. 9).

Baltisphaeridium striatoconus (Deflandre and Cookson)

(Pl. 11, fig. 9)

Hystrichosphaeridium striatoconus Deflandre & Cookson 1955, p. 275.
Hystrichosphaeridium striatoconus Deflandre & Cookson, Cookson & Eisenack 1960, p.8.
Baltisphaeridium striatoconus (Deflandre & Cookson) Downie & Sarjeant 1963, p. 91.

COMMENT: Until recently, when Evans (1961) reported the occurrence of *B. striatoconus* in the Port Campbell No. 1 Bore in SW. Victoria between 5700 and 5705 ft, this distinctive species had been known only from Western Australia. Evans estimated the age at this level as Cenomanian on the basis of the occurrence of *Deflandrea acuminata* Cookson & Eisenack (1958) originally described from the upper part of the Gearle siltstone from West Australian Petroleum Co. Rough Range No. 5 Bore at 1570 ft and No. 8 Bore between 1530 and 1548 ft, the age of which had been regarded as Cenomanian to Turonian.

A second Victorian occurrence of *B. striatoconus* can now be reported namely in deposits intersected by the Port Campbell No. 2 Bore between 7403 and 7408 ft, and 7440 and 7750 ft, the age of which is suggested by Taylor (1964) as Turonian. In these deposits, as well as in the Port Campbell No. 1 Bore, *B. striatoconus* is associated with the pollen tetrad *Amosopollis cruciformis* Cookson & Balme 1962, p. 99.

The association of these two forms in Victoria is of stratigraphical interest. As far as is known both forms had restricted time-ranges. In Western Australia the time-range of B. *striatoconus* appears to have been from Turonian to Santonian. A Turonian age was indicated by its occurrence in the Upper Gearle Siltstone, Rough Range South Bore between 2500 and 2514 ft, the age estimated by Dr M. F. Glaessner (unpublished report to WAPET). A Santonian age has been suggested by Dr H. S. Edgell (pers. com.) for the Molecap Greensand from which *B. striatoconus* was first recovered. The time-range given by Cookson & Balme (1962) for the Western Australian occurrence of *Amosopollis cruciformis* is Albian to Cenomanian.

From the present evidence it would appear that the ranges of *A. cruciformis* and *B. striatoconus* are extended and overlap. This overlap probably represents Upper Cenomanian to Lower Turonian times.

A similar association of *B. striatoconus* and *A. cruciformis* occurs in the Balcatta No. 1 Bore, Perth Metropolitan area, Western Australia between 180 and 210 ft. In the deposit intersected between 220 and 277 ft in this bore, *A. cruciformis* occurs together with such forms as *Actinotheca aphroditae* Cookson & Eisenack 1960 (Turonian), *Gillinia hymenophora* Cookson & Eisenack 1960 (Upper Turonian to Senonian), *Cyclodictyon paradoxus* Cookson & Eisenack 1960 (Cenomanian to Lower Turonian), and *Deflandrea* cf. *acuminata* Cookson & Eisenack (1958) (Cenomanian to Lower Turonian).

Class CHLOROPHYCEAE

(Order PROTOCOCALES?)

Family Uncertain

Palambages O. Wetzel

Palambages Form A Manum & Cookson

(Pl. 11, fig. 5-8; 8, P23038; 5, P23039; 7, P23093)

Palambages Form A Manum & Cookson 1964.

AGE AND OCCURRENCE: Albian: SANTOS Oodnadatta No. 1 Bore, South Australia at 327 ft. Lower Upper Cretaceous: Frome Broken Hill Co. Flaxman's No. 1 Bore W. of Port Campbell between 6375 and 6391 ft, 6663 ft; Port Campbell No. 2 Bore between 7403 and 7408 ft; Port Campbell No. 3 Bore between 4610 and 4620 ft, and 4650 and 4670 ft. Upper Cretaceous, ?Senonian or younger: Eumeralla No. 1 Bore NW. Port Fairy, Victoria, cuttings taken between 3020 and 3030 ft, 3080 and 3090 ft; 3100 and 3110 ft.

COMMENT: Clusters of cells suggestive of green algal colonies were first recorded from Baltic Senonian and Danian flints by O. Wetzel (1934) under the provisional name *Morulosae*. In 1961, Wetzel established the genus *Palambages* for these colonies with the type species *P. morulosa*. Comparable colonies and a new species have since been recorded from Maestrichtien deposits in Poland (H. Górka 1963) and 3 forms, *Palambages* Forms A, B, and C, described by Manum & Cookson (1964) from lower Upper Cretaceous deposits in Graham and Ellef Ringnes Islands, Arctic Canada.

The distribution of *Palambages* can now be extended to the Southern Hemisphere as the result of the recovery of colonies referable to it from the SE. Australian Albian and Upper Cretaceous deposits mentioned above. In these colonies the number of cells per individual has varied considerably and usually exceeded that given by Wetzel for *P. morulosa*. In this and other respects the Australian specimens agree most closely with *P.* Form A Manum & Cookson 1964, with which it seems best to associate them until such time as more is known about the genus as a whole and the characters upon which individual species can reliably be based.

The cells of the Australian examples are *c.* 12-21μ in diameter and the number of cells per colony seems to range between 12 and 60. The walls of the cells are smooth or finely granular in profile, finely dotted in surface view.

Acknowledgements

I wish to thank Professor A. Eisenack, Dr W. R. Evitt, and Dr G. Baker for helpful suggestions, and Mr D. J. Taylor for information regarding the age of the Brown's Ck sediments. Samples were generously provided by Dr O. P. Singleton, University of Melbourne, Mr D. J. Taylor, Mines Department of Victoria, and Mr A. McQueen, Frome Broken Hill Company.

References

Brosius, Marita, 1963. Plankton aus dem nordhessischen Kasseler Meeressand (Oberoligozän). *L. deutsch. geol. Ges.* 114: 32-56.

Carter, A. N., 1958. Tertiary Foraminifera from the Aire District, Victoria. *Geol. Surv. Vic. Bull.* 55.

Cookson, Isabel C., 1953. Records of the occurrence of *Botryococus brauni Pediastrum* and Hystrichosphaerideae in Cainozoic deposits of Australia. *Mem. Nat. Mus. Melb.* 18: 107-123.

Cookson, Isabel C., and Balme, B. E., 1962. *Amosopollis cruciformis* gen et sp. nov. A pollen tetrad from the Cretaceous of Western Australia. *Proc. Roy. Soc. W.A.* 45: 97-99.

Cookson, Isabel C., and Eisenack, A., 1958. Microplankton from Australian and New Guinea Upper Mesozoic sediments. *Proc. Roy. Soc. Vict.* 70: 19-78.

————, ————, 1960. Microplankton from Australian Cretaceous sediments. *Micropaleontology* 6: 1-18.

————, ————, 1961. Tertiary microplankton from the Rottnest Island Bore, Western Australia. *J. Roy. Soc. W.A.* 44: 39-47.

————, ————, 1962. Some Cretaceous and Tertiary microfossils from Western Australia. *Proc. Roy. Soc. Vict.* 75: 269-273.

Deflandre, G., and Cookson, Isabel C., 1955. Fossil microplankton from Australian Late Mesozoic and Tertiary sediments. *Aust. J. Mar. Freshw. Res.* 6: 242-313.

Deflandre, G., and Courteville, H., 1939. Note préliminaire sur les microfossiles des silex crétacés du Cambrésis. *Bull. Soc. Française Microscopie* 8: 95-106.

Downie, C., and Sarjeant, W. A. S., 1963. On the interpretation and status of some hystrichosphere genera. *Palaeontology* 6: 83-96.

Evans, P. R., 1961. A palynological Report on F. B. H. Port Campbell No. 1 and 2 Wells, Victoria. *Bureau Min. Res. Geol. and Geophysics Records* No. 63.

Gerlach, Ellen, 1961. Mikrofossilien aus dem Oligozän und Miozän Nordwestdeutschlands. *N. Jb. Geol. Paläont* 112: 143-228.

Górka, Hanna, 1963. Coccolithophoridés, Dinoflagellés, Hystrichosphaeridés et microfossiles Incertae Sedis du Crétacé Supérieur de Pologne. *Acta Palaeontologica Polonica* 8: 1-90.

Manum, S., and Cookson, Isabel C., 1964. Cretaceous microplankton in a sample from Graham Island, Arctic Canada, collected during the second "Fram"-expedition (1898-1902). *Norske Vid-Akad. Skrifter 1 Mat-Naturv.* Klasse No. 17: 1-36.

Taylor, D. J., 1964. Foraminifera and the stratigraphy of the Western Victorian Cretaceous sediments. *Proc. Roy. Soc. Vict.* 77: 535.

Wetzel, O., 1933. Die organischer substanz erhaltenen mikrofossilien des baltischen Kreide Feurersteins. *Palaeontographica* 78: 1-104.

————, 1961. New microfossils from Baltic Cretaceous flintstones. *Micropaleontology* 7: 337-350.

Explanation of Plates

Magnifications × *c.* 670 unless otherwise stated.

Plate 9

Fig. 1, 2, 3, 5-12—*Diphyes colligerum* (Deflandre & Cookson) Brown's Creek Greensand. 1, ventral surface × *c.* 1,000; 2, dorsal view; 3, a specimen with short, stiff appendages in ventral view; 5-7, three views of the same specimen; 5, surface view of apex; 6, deeper view showing inner surface of antapex and the small wall-thickenings around it; 7, dorsal view × *c.* 480; 8, 9, posterior portion of a shell at two foci showing circle of small prominences; 10, portion of wall of anterior part of shell showing base of an appendage in surface view and a complete appendage the cavity of which is visible for about half its length × *c.* 1500; 11, surface view of an antapex showing circle of prominences and position of future opening; 12, antapex showing position of opening.

Fig. 4—*D. colligerum*, from an Upper Cretaceous deposit between 3050 and 3060 ft in Eumeralla Bore, SW. Victoria.

PLATE 10

Fig. 1-4—*Diphyes nudum* n.sp. Brown's Ck Greensand.

Fig. 5-9—*Baltisphaeridium nanum* Brown's Ck; 5-6, carbonaceous clay below Greensand × *c.* 1500; 7-9, Greensand; 9, showing opening.

Fig. 10-12—*Hologinella? spinosa* n.sp. Brown's Ck. 10, Greensand showing minute dots over the general surface; 11-12, gritty clay 40-50 ft above Greensand; 11 × *c.* 1100.

Fig. 13—*Hologinella incurvata* Cookson & Eisenack. Brown's Ck Greensand.

PLATE 11

Fig. 1-3a—*Hystrichosphaeridium ellipticum* n.sp. Brown's Ck Greensand. 3a, a primary process showing a central cavity and secondary and tertiary branches × *c.* 1500.

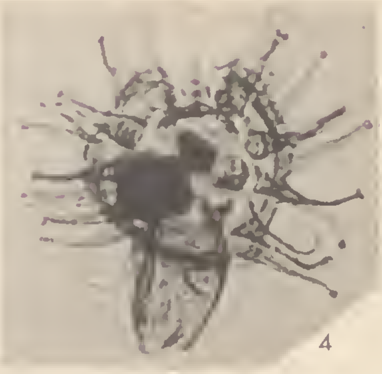
Fig. 4—*Cyclonephelium retiintextum* n.sp. Eumeralla No. 1 Bore between 3090 and 3100 ft × *c.* 480.

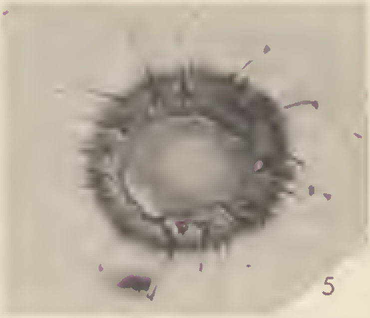
Fig. 5-8—*Palambages* Form A Manum & Cookson. 5, 8, Eumeralla No. 1 Bore; 5, at 3080 ft *c.* 16-celled colony × 1150; 8, between 3050 and 3060 ft *c.* 12-celled colony; 6, 7, Flaxmans No. 1 Bore between 6379 and 6391 ft. 7, *c.* 60-celled colony.

Fig. 9—*Baltisphaeridium striatoconus* (Deflandre & Cookson) Port Campbell No. 2 Bore between 7603 and 7608 ft.

Fig. 10—*Hologinella? spinosa* n.sp. Brown's Ck, calcareous clay 15 ft above Greensand.

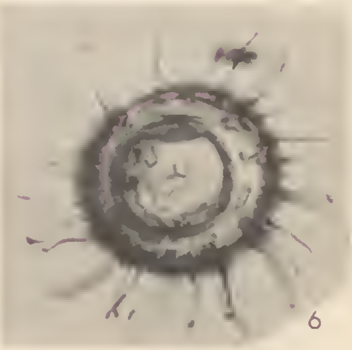

1


4


5


2


3

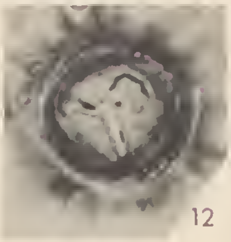

6

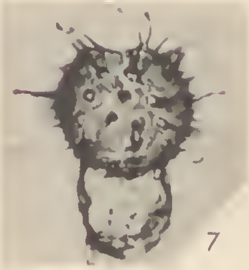

10


9


8


11


12

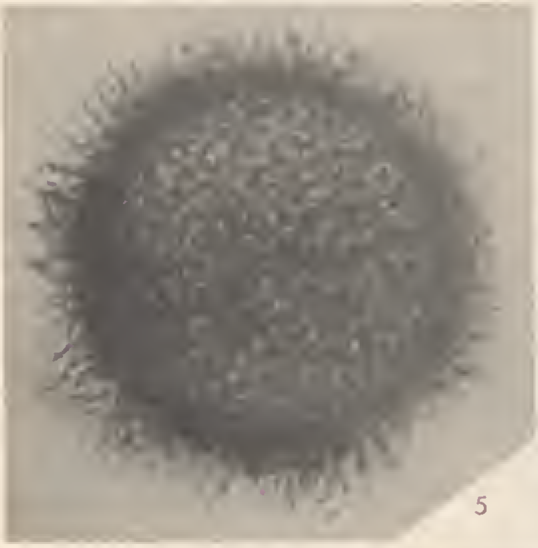

7

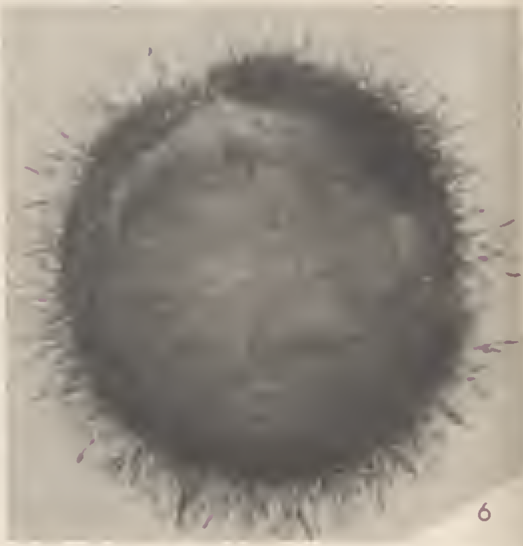

1

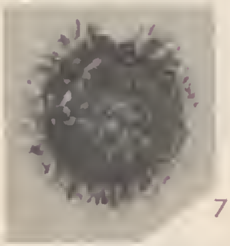

2


3


4

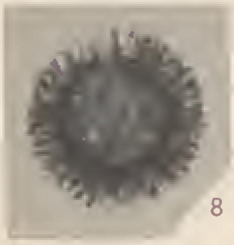

5

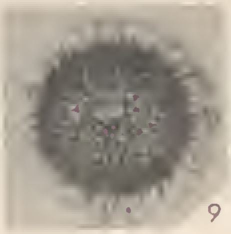

6


7


10


11


8

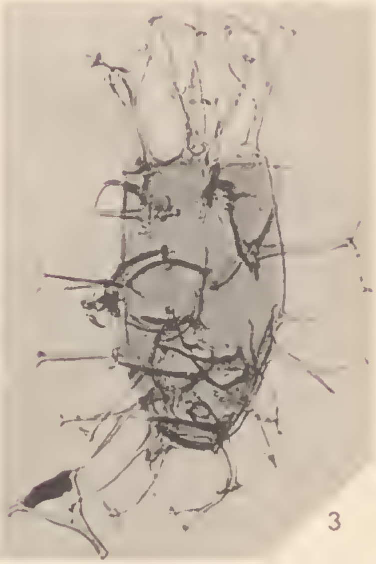

9


13

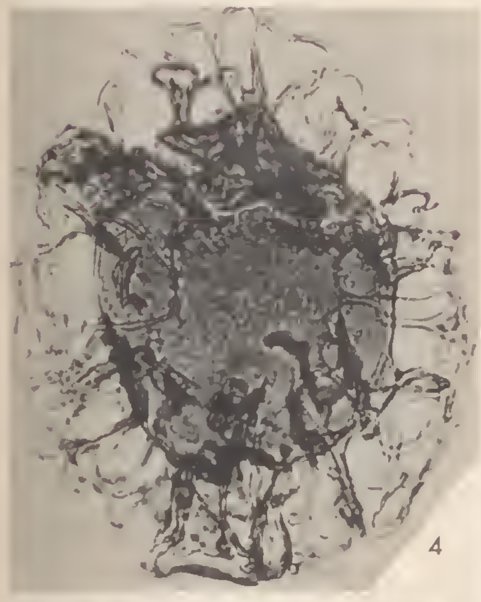

12

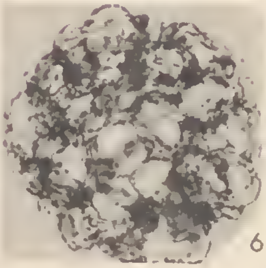

1

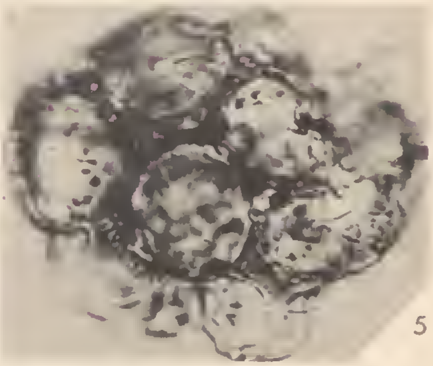

2

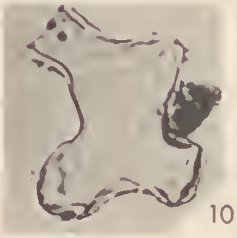

3

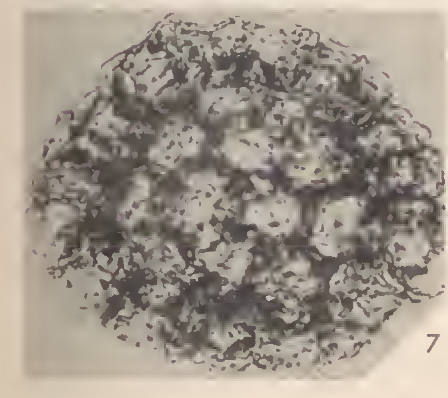

3a

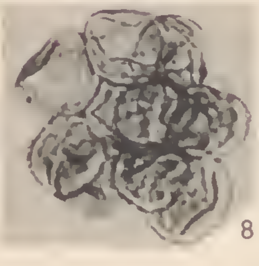

4

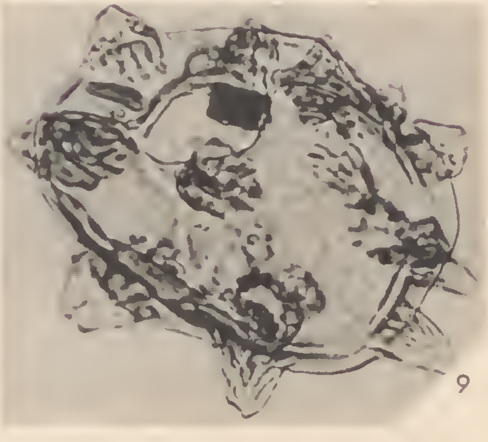

6


5


10


7


8


9

5

REVISION OF THE SPECIES OF *EUCRASSATELLA* AND *SPISSATELLA* IN THE TERTIARY OF VICTORIA AND TASMANIA

By THOMAS A. DARRAGH
Geology Department, University of Melbourne

Abstract

Eucrassatella and *Spissatella* are crassatellid molluscs with resilifers extending from the beak to the ventral edge of the hinge plate and generally with smooth internal ventral margins. Five new species of *Eucrassatella* are described and other species redescribed. *Spissatella* is recorded from Australia for the first time. New species described are *Eucrassatella eupontica, E. dorsennata, E. rosicollina, E. deltoides* and *E. memanae.*

Introduction

The larger Tertiary crassatellid genera are *Crassatella* Lamarck (= '*Crassatellites*' auct.), *Bathytormus* Stewart, *Eucrassatella* Iredale, *Hybolophus* Stewart and *Spissatella* Finlay. *Crassatella* has a crenulated internal ventral margin and a resilifer extending from the beak halfway to the ventral border of the hinge plate (Stewart 1930, p. 136). *Spissatella* and *Eucrassatella* possess a resilifer extending from the beak to the ventral edge of the hinge plate. *Bathytormus* from the Palaeogene of North America and Europe and *Hybolophus* from the Neogene of North and Central America also have this feature; however, the former has a crenulated internal ventral margin which is absent in *Eucrassatella, Hybolophus,* and all species of *Spissatella* except early Tertiary species such as *Spissatella australis* (Hutton). *Bathytormus* also differs from *Eucrassatella* and *Spissatella* by having greater development of tooth 4b. *Spissatella* is generally smaller than *Eucrassatella,* has a more angular outline, and a prominent tooth 3a. *Hybolophus* has opisthogyral or orthogyral umbones, a sinuous ventral margin, and rather elongate anterior laterals.

Prior to the present work only two genera of the larger crassatellids have been recognized in the Australian Tertiary, *Eucrassatella* and *Crassatella.* The former was represented by 4 species—*Eucrassatella oblonga* (Tenison Woods), *E. maudensis* (Pritchard), *E. kingicoloides* (Pritchard), and *E. camura* (Pritchard); the latter by *Crassatella dennanti* Tate, a species similar to the typical crassatellids of the Palaeogene of Europe. *Crassatella dennanti* is not dealt with in this revision. This revision shows that *Crassatellites maudensis* Pritchard from Torquay is congeneric with certain New Zealand species belonging to the genus *Spissatella.*

Table 1 summarizes the stratigraphical and geographical distributions of the various species.

Geographical Distribution

RECENT SPECIES: The only living larger crassatellids are *Crassatella* s.l. *Eucrassatella* and *Hybolophus. Eucrassatella* is confined to Australian waters, having a distribution from Torres Strait down the E. coast, to the N. coast of Tasmania, across southern Australia, and up the W. coast. Species from the Central American region (California to Peru and the West Indies) do not belong in *Eucrassatella* but in *Hybolophus.* No living species have been recorded from New Zealand or Japan.

TABLE 1

Eucrassatella		
oblonga	Janjukian (Upper Oligocene)	Fossil Bluff near Wynyard, Tasmania
eupontica	(Balcombian?) Bairnsdalian (Middle (?) Miocene)— Cheltenhamian (Upper Miocene)	Port Phillip, Gippsland
rosicollina	Upper Mitchellian (Upper Miocene)	Gippsland
dorsennata	Cheltenhamian—Lower Kalimnan (Lower Pliocene)	Gippsland, W. District; ? Adelaide
camura	Cheltenhamian—Kalimnan	W. District
kingicoloides	Upper Cheltenhamian—Kalimnan	Gippsland
deltoides	Middle (?) Pliocene	Flinders Is.
memanae	Upper (?) Pliocene	Flinders Is.
Spissatella		
maudensis	Janjukian	Port Phillip, (?) Gippsland
Crassatella		
dennanti	Batesfordian (Lower Miocene)—Bairnsdalian	Gippsland, Port Phillip, W. Victoria

FOSSIL SPECIES: *Eucrassatella* is widespread in the Tertiary of southern Australia occurring in Gippsland, C. and W. Victoria, the Murray Basin, and the Adelaide Basin in South Australia, Flinders Is., and the N. coast of Tasmania. In the Tertiary of New Zealand there are at least two species (*E. ampla* (Zittel) and *E. attenuata* (Hutton)). The author has examined an undescribed species from the Miocene of the Mai Mai Dome, New Guinea, and the genus has been recorded from the Tertiary of Japan. Mizuno (1952) records three species from the Oligocene, two of which he doubtfully places in the genus; judging from the original figures and description (Nagao 1928) the third species, *Crassatellites yabei* Nagao, is a true *Eucrassatella.* Shuto's record (1952) of the genus from the Upper Miocene of Japan is based on a fragmentary specimen whose generic placement cannot be determined from the illustration. Records of the genus from North and South America are based on species which appear to belong in *Hybolophus.*

The genus *Spissatella,* hitherto only recorded from the Tertiary of New Zealand, also occurs at Torquay, possibly at Maude near Geelong, and in Gippsland, all in Victoria.

Habitat

DEPTH: Vereo (1905, p. 169) dredged specimens of *Eucrassatella donacina* (Lamarck) from South Australia in 15-20 fathoms and later (1907) dredged specimens in 40 and 100 fathoms 'both small and poor'. Iredale (1924, p. 202) recorded *Eucrassatella kingicola* (Lamarek) taken by Roy Bell in Twofold Bay from depths ranging from 15 to 25 fathoms. Macpherson & Gabriel (1962, p. 315) record the same species from 8 fathoms in Western Port and the author examined dredged specimens in Western Port from 6 to 8 fathoms. The available information seems to suggest that the southern members of the genus, at least, are common in the offshore neritic zone. Fossil members of the genus presumably lived in similar depths.

NATURE OF BOTTOM SEDIMENT: Little information is available on the nature of the bottom sediment on which the recent species live. Iredale (1924, p. 202) recorded specimens dredged from coarse sand to soft mud in Twofold Bay, N.S.W., and the author has examined dredged specimens from coarse shell sand in Western Port Bay, Vict. Fossil species are found in sediments ranging from coarse sand (basal Freestone Cove Sandstone at Fossil Bluff) to fine silts (Newport Formation at Altona). However, specimens from very fine sediments are rare, as in the Newport Formation and the Bullenmerri 'Clay'. The fossils are common only in those fine sediments with a high proportion of coarse broken shell material such as the Jemmy's Point Formation. Frequently beds are composed almost entirely of *Eucrassatella* and broken shells, as in the lower shell band at Jemmy's Point.

Stratigraphical Distribution

The proved time range of *Eucrassatella* in Australia is from Janjukian (Upper Oligocene) to the present. Possibly the earliest Australian fossil *Eucrassatella* is a complete left valve from the Upper Eocene of Point Flinders (AW1) near Cape Otway collected by Wilkinson in 1864, but, despite a search of all available collections and an examination of the locality itself, no further examples have been found. Unfortunately no matrix is preserved on the specimen so that the locality cannot be verified. The specimen superficially resembles *Eucrassatella eupontica* sp. nov.

The oldest undoubted species is *Eucrassatella oblonga* from the Janjukian (Upper Oligocene) of Fossil Bluff near Wynyard, Tasmania. The *Eucrassatella* species from Japan are recorded from somewhere in the Oligocene. Finlay and Marwick (1940) give the time range for *Eucrassatella* in New Zealand as Hutchinsonian (Lower Miocene) to Waitotarian (Lower Pliocene).

Marwick (1960) gives the range of *Spissatella* in New Zealand as Matau series (Paleocene) to Taranaki series (Upper Miocene). In Victoria the genus is restricted to the Janjukian.

Hinge Terminology

The notation used to describe the teeth is that of Munier-Chalmas and is based on Lamy (1917) who considered the crassatellid tooth pattern to be lucinoid. There has been confusion in the placing of the Astartacea within the heterodonts, some authors placing the superfamily with the lucinoids, others with the cyrenoids. Davies (1935) considered that the hinge was lucinoid but had been modified to give a cyrenoid appearance by the addition of an extra tooth 5b in the right valve. He split off the Astartacea and Carditacea from the lucinoids and cyrenoids because of this peculiarity. Korobkov (1954) retains Davies's three divisions giving them the formal names Lucinodonta, Astartedonta and Cyrenodonta. He has retained the lucinoid formula in his notation of the hinge of the Astartedonta.

Measurements

Measurements on the valves have been made either parallel to a line joining the muscle scars or perpendicular to this line. The following symbols are used: L-Length of valve, A-maximum distance of the beak from the anterior margin, H-maximum height of valve, T-maximum thickness of valve, U-distance of the umbo to the ventral margin directly beneath the beak. $\frac{L}{U}$ and $\frac{A}{L}$ are ratios of these measurements. All measurements are in millimetres.

Siphonal Ridge

No suitable term appears to exist for the external ridge which runs from the umbo to the posterior ventral corner of each valve. The ridge is the anterior edge of the siphonal area. The term siphonal ridge is used in the descriptions for this feature.

Material

The bulk of the specimens used in this study are housed in the National Museum of Victoria. The Cudmore, Pritchard, and Colliver collections have provided large suites of topotypic material. These collections have been supplemented by material collected by the author and that borrowed from Dr O. P. Singleton, Mr J. Hollis, the University of Adelaide, the Mines Department of South Australia, the Commonwealth Palaeontological Collection, the Tasmanian Museum, and the Melbourne University Geology Department. Registered numbers quoted throughout are prefixed by a symbol identifying the institution to which they belong, thus—

National Museum of Victoria—P
Melbourne University Geology Department—MUGD
Commonwealth Palaeontological Collection—F or CPC
Tasmanian Museum—B and Z.

Systematic Descriptions

Suborder ASTARTEDONTA Korobkov 1954

Hinge lucinoid but with greater development of tooth 3b and introduction of 5b.

$$\text{Formula}\qquad \frac{\text{AI}\quad \text{AIII}\quad 3\text{a}\quad 3\text{b}\quad 5\text{b}\quad \text{PI}\quad \text{PIII}}{\text{AII}\quad \text{AIV}\quad 2\quad 4\text{b}\qquad\quad \text{PII}\quad \text{PIV}}$$

Superfamily ASTARTACEA

Family CRASSATELLIDAE Gray

Genus **Eucrassatella** Iredale 1924

Eucrassatella Iredale 1924, *Proc. Linn. Soc. N.S.W.* 49 (3): 202.

Type species (original designation): *Crassatella kingicola* Lamarck 1805.

Shell thick, heavy, equivalve, ovate to sub-oblong, occasionally subquadrate. Umbo prosogyral. Siphonal ridge present. Lunule and escutcheon deeply impressed. Ornament consisting of concentric ribs usually confined to the umbonal region, occasionally entirely absent or extending to the ventral border of the valve.

Hinge plate short and with a large triangular resilifer extending from under the beak to the ventral edge of the hinge plate. Ligament pit narrow, posterior to the resilifer. Tooth formula $\frac{3\text{a}\quad 3\text{b}\quad 5\text{b}\quad \text{LPI}}{\text{LAII}\ 2\quad 4\text{b}}$. Laterals are variable and are poorly developed in most cases being an extension of the valve margin. 3b is strongly developed and has its sides grooved, 3a and 5b usually not well developed, 5b has no corresponding socket in the left valve.

Pallial line simple and impressed. Pedal impression deep beneath the hinge plate and just behind the anterior muscle scar. Muscle scars large sub-equal deeply impressed, the anterior scar a little elongated dorso-ventrally, the posterior scar sub-circular.

Interior of shell porcellaneous. Ventral margin of the valves smooth without crenulations.

Eucrassatella kingicola (Lamarck 1805)

(Pl. 15, Fig. 38-40)

Crassatella kingicola Lamarck 1805, *Ann. Mus. Hist. Nat. Paris* 6: 409. Lamarck 1818, *Histoire naturelle des animaux sans vertèbres* 5: 481. Lamy 1917, *Jour. de Conchyl.* 62 (4): 205, Pl. 6, fig. 1 (q.v. for complete synonomy).

Type Locality: King Is., Bass Strait. Collected by Peron and Leseuer.

Location of Type: Museum d'Histoire Naturelle de Paris.

Stratigraphical Range: (?) Werrikooian (U. Plio.-L. Pleist.) to Recent.

Geographical Distribution: Southern N.S.W., Bass Strait, N. coast of Tasmania.

Discussion: The species is represented in the Werrikooian by one valve collected by G. B. Pritchard (P23064) from Limestone Ck, Glenelg R. The holotype is not typical of the species, being rather ovate; generally the species is more rostrate i.e., the posterior is produced into a flare. Two specimens, one from Tasmania, the other from Twofold Bay, N.S.W. in the collection of the Australian Museum (Reg. No. C42191 & C49906 respectively), compare well in shape with the holotype. Lamy (1913, p.101 footnote) has discussed the authenticity of Lamarck's type specimens and concludes that the specimen illustrated is authentic. The locality written on the shell is apparently in the handwriting of Lamarck.

The name *Crassatella kingicola* is first given without description on p. 408 of Lamarck 1805. However, on p. 409, when describing the fossil *Crassatella tumida* from Grignon, he validates the name *Crassatella kingicola* by giving a brief description when comparing the living species with the fossil.

Eucrassatella oblonga (Tenison Woods 1876)

(Pl. 12, fig. 4, 9-10; Pl. 14, fig. 21)

Crassatella oblonga Tenison Woods 1876, *Proc. Roy. Soc. Tas.* for 1875: 25, fig. 11. Johnston 1888, *Geol. Tas.* Pl. 29, fig. 1, la. Pritchard 1896, *Proc. Roy. Soc. Vict.* 8: 131.
Crassatella aphrodina Tension Woods 1876, *Proc. Roy. Soc. Tas.* for 1875; 24, fig. 12. Johnston 1888, *Geol. Tas.* Pl. 29, fig. 2. Pritchard 1896, *Proc. Roy. Soc. Vict.* 8: 131.

Description of Holotype: B42 Z174, left valve.

Shell large, very elongate, somewhat rectangular; umbo prosogyral situated about $^{10}/_{27}$ of the length of the valve from the anterior end. Anterior dorsal margin straight, posterior dorsal margin straight then curving out above the posterior muscle scar, truncated by the short, straight posterior margin. Anterior margin short and very convex, hardly differentiated from the dorsal and ventral margins. Ventral margin gently convex. Siphonal ridge present but not prominent, siphonal area very narrow and somewhat concave. Hinge plate thick, wide, rather short about $^{2}/_{7}$ of the vertical diameter of the valve.

Teeth. LAII short but prominent, socket for 3a very narrow considerably encroached upon by the lunule, 2 prominent sloping slightly to the anterior, 4b thin somewhat higher and pointed at its ventral end, virtually obsolete. Posterior laterals obsolete. Ligament pit narrow rather deeply impressed, separated from the large resilifer by a slight rise.

Ventral margin of shell smooth.

Exterior of valve ornamented with fine growth striae.

Description of Hypotype: P23073, right valve.

Shell relatively shorter than the holotype. Posterior end only sightly flared.

Teeth. Anterior lateral absent. 3a short, not very prominent, grooved on inner side, somewhat encroached upon by the lunule, 3b grooved somewhat triangular very prominent, sloping posteriorly, socket for 2 wide and deep. 5b thin virtually obsolete, socket for 4b small and circular, LAI long and prominent.

Valve ornamented with fine growth striae, umbo with 19 thin ribs extending 11 mm from the beak, inter-rib spaces as wide as the ribs.

Dimensions:

Holotype	B42 Z174	L95	A26	H66	T19	U63	$\frac{L}{U}$1·50	$\frac{L}{A}$3·6	
Hypotype	P23073	76	18	57	15	53	1·44	4·2	Lower Bed
Type of *aphrodina*	B27 Z199	54	17	44	—	42	1·29	3·2	
	P22462	60	19	52	15	51	1·18	3·2	Upper Bed
	P22469	98	33	73	23	71	1·38	3·0	Upper Bed
	P22434	73	24	55	15	54	1·35	3·1	Lower Bed
					(Worn)				

Location of Type: Holotype B42 Z174, Tas. Mus., Hobart. Type of *aphrodina* B27 Z199 Tas. Mus., Hobart. Hypotype P23073 Nat. Mus. Vict., collected by F. S. Colliver.

Type Locality: 'Table Cape' i.e., Fossil Bluff near Wynyard, Tas. Matrix indicates that the holotype came from the Freestone Cove Sandstone of the Table Cape Group i.e., the lower or *Crassatella* Bed. Matrix indicates that the type specimen of *Crassatella aphrodina* comes from the Fossil Bluff Sandstone of the Table Cape Group i.e., the upper or *Turritella* Bed. Age Janjukian.

Stratigraphical Distribution: Janjukian (Upper Oligocene or Lower Miocene).

Occurrence: Fossil Bluff near Wynyard, Tasmania.

Material: Type specimens. 40 specimens from the Freestone Cove Sandstone. 12 specimens from the Fossil Bluff Sandstone.

Comments: The exterior of the holotype has the umbonal ribs and growth striae worn away, a common feature of specimens from the lower bed at Fossil Bluff. The posterior end of the valve is broken, about 1-2 mm of the valve is missing, this is shown in Tenison Woods's original figure. The exterior of the valve has two labels attached, the upper with 'Type' written thereon, the lower '*Crassatella oblonga*' in faded ink.

The writer agrees with Pritchard (1896, p. 131), Dennant and Kitson (1903, p. 124), and May (1919, p. 105) that *Crassatella aphrodina* is synonymous with *Crassatella oblonga*. Tenison Woods has chosen an extremely elongate specimen of *oblonga* for a type. Generally, specimens are not as elongated and the posterior flare is not as pronounced. The figured hypotype illustrates the typical shape of the species. In some specimens, particularly those from the upper bed, the anterior dorsal margin is slightly concave giving the umbo a more pointed and prominent appearance. Of the large number of specimens available to the writer from the Lower bed at Fossil Bluff, none can be matched exactly with the type specimen, though some specimens approach it in size and shape; the $\frac{L}{U}$ ratio 1·50 is the largest recorded from a group of 50 specimens.

The type of *Crassatella aphrodina* is an immature specimen comprising a pair of cracked valves. Part of the left valve is missing. It is considerably less elongate than the type of *C. oblonga,* having a $\frac{L}{U}$ ratio of 1·29, a few specimens from the upper bed at Fossil Bluff are even less elongate having a $\frac{L}{U}$ ratio of 1·15. The series of specimens available shows a gradation from *C. aphrodina* through to *C. oblonga.*

Although the name *C. aphrodina* has page priority, *C. oblonga* is better known and has been used as the name for the Table Cape shell for many years, and as *C. aphrodina* has been founded on a damaged, immature specimen it would seem preferable to retain the name *C. oblonga* for the *Eucrassatella* from Fossil Bluff.

Eucrassatella eupontica sp. nov.

(Pl. 13, fig. 13-14, 16; Pl. 15, fig. 32)

ETYMOLOGY: Greek eu = fair, pontos = sea, translation of place name Beaumaris.

DESCRIPTION OF HOLOTYPE: P23074, right valve.

Valve subtrigonal slightly elongate. Umbo small, not prominent prosogyral situated ⅓ of the valve length from the anterior end. Anterior and posterior dorsal margins straight, the anterior sloping away from the umbo at a steeper angle. Anterior margin gently convex passing into a convex ventral margin. Posterior margin straight obliquely truncating the dorsal and ventral margins. Posterior end of the valve scarcely attenuated.

Siphonal ridge straight, not prominent, tending to fade towards the ventral margin.

Teeth. 3a very thin, 3b thick, prominent, sloping anteriorly, 5b relatively thick. LPI very long. Socket for 2 as wide as 3b.

Resilifer rather narrow, ligament pit well differentiated from the resilifer.

Ventral margin of valve smooth.

Umbo ornamented with 22 concentric ribs fading out 1·0 cm from the beak. Surface of valve ornamented with fine growth striae.

DESCRIPTION OF PARATYPE: P23075-6, pair.

Shell more elongate than the holotype and rather tumid. Posterior dorsal margin concave. Siphonal ridge prominent.

Teeth. LAII very short, 2 short and thick, 4b not prominent.

Umbo ornamented with 18 ribs fading out 0·7 cm from the beak. The remains of the resilium were found in the resilifer when the valves were separated.

DIMENSIONS:

Holotype	P23074	L69	A23	H56	T14	U54	$\frac{L}{U}$ 1·28	$\frac{L}{A}$ 3·0	Beaumaris
Paratype	P23075	60	21	49	17	48	1·25	2·9	Warrambine Ck
	P23077	79	30	67	19	66	1·20	2·6	Beaumaris

LOCATION OF TYPES: Nat. Mus. Vict., holotype P23074, Cudmore collection. Paratype P23075-6, collected by T. A. Darragh.

TYPE LOCALITY: Shell bed immediately above the nodule bed, Beaumaris, Vict. Black Rock Member of the Sandringham Sands Formation. Age Cheltenhamian (U. Mioc.)

Stratigraphic Range: Balcombian(?) Bairnsdalian-Cheltenhamian.

Occurrence: Altona Bay Coal Shaft No. 2, 2 specimens. (?) MacRae's Quarry upstream from Princes H'way Toorloo Arm, Gippsland. Present as moulds in limestone.

Bairnsdalian	Warrambine Ck near Inverleigh, Grid Ref. 090982, Geelong, common.
Mitchellian	Moondara Farm, F72 GSV, Bairnsdale, Grid Ref. 512341, 1 specimen.
	Lakes Entrance Oil Shaft. Exact horizon unknown but between 10-150 ft. The matrix suggests that some of the fossils came from the 'greenish-grey sandy marls with glauconite' at 50-150 ft. The age of the sediments at this depth is probably Cheltenhamian.
	Bore, Parish of Yeerung, Gippsland, 380 ft, 1 specimen.
	Bore No. 3, Parish of Moormurng, 260 ft, 1 specimen.
Cheltenhamian	Beaumaris above the nodule bed, common.

Material: Type and 26 specimens Beaumaris, 11 specimens Warrambine Ck.

Comment: This species differs from *E. kingicoloides* in having a prominent prosogyral umbo and lacking the marked posterior attenuation of the shell. The fossil species closest to *E. eupontica* is *E. oblonga* which is generally more elongate, has more produced umbos, and a greater attenuation of the posterior end.

Eucrassatella rosicollina sp. nov.

(Pl. 12, fig. 5-7)

Etymology: Rose Hill, the old name for the type locality.

Description of Holotype: P23078, right valve.

Valve roundly pentagonal, somewhat flattened. Umbo depressed, prosogyral situated ⅖ of the valve length from the anterior end. Anterior dorsal margin slightly convave, posterior dorsal margin slightly convex. Anterior margin strongly convex, ventral margin slightly convex, posterior margin very slightly convex symmetrically truncating the ventral and posterior dorsal margins. Posterior end of valve very little attenuated.

Siphonal ridge weakly developed but not fading as it approaches the ventral margin.

Hinge plate ⅙ umbo ventral diameter.

Teeth. 3a rather strongly developed, 3b prominent, lateral grooving reduced, 5b obsolete. LPI prominent, narrow and wedge shaped. Socket for 2 rather wide. Resilifer rather narrow, external ligament pit very wide.

Umbo ornamented with 9 ribs, these fade out 3 mm from the beak. Ribs are absent on the initial 0·5 mm and on the area posterior to the siphonal ridge. Surface of valve ornamented with fine growth striae.

Description of Paratype: P23079, left valve.

The valve is similar in shape to the holotype.

Teeth. LAII thin prominent, 2 thin not prominent, 4b thin obsolete, the teeth have no lateral grooves. LPII short and prominent. Socket for LPI curved and wedge shaped fading into the hinge plate as it approaches the external ligament area.

Umbo ornamented with 8 ribs which fade out 3 mm from the beak.

DIMENSIONS:

Holotype	P23078	L64	A25	H50	T14	U50	$\frac{L}{U}$ 1·28	$\frac{L}{A}$ 2·5
Paratype	P23079	65	28	52	15	52	1·25	2·3
Paratype	F17001	65	27	52	13	52	1·25	2·4
	P23040	65	27	50	15	50	1·18	2·4
	P23041	64	25	53	14	53	1·20	2·6

LOCATION OF TYPES: Nat. Mus. Vict., holotype P23078, collected by T. A. Darragh. Paratype P23079. Tate Museum, University of Adelaide, paratype F17001.

TYPE LOCALITY: Moondara Farm (part of the old Rose Hill) near E. fence of the bull paddock behind the milking shed, about half way up bank. Grid Ref. Bairnsdale 512341, GSV F72. Tambo River Formation. Age Uppermost Mitchellian.

OCCURRENCE: Type locality.

MATERIAL: Type specimens, 16 topotypes. 1 specimen, 'Rose Hill' CPC F3794.

COMMENTS: The species is recognized by its pentagonal outline, the depressed umbo, reduced umbonal ornament, the smooth cardinal teeth, and the wedged shaped posterior lateral tooth of the right valve. This species does not resemble any Australian *Eucrassatella* but is very similar in the hinge structure and general appearance to the New Zealand *Eucrassatella attenuata* (Hutton).

Eucrassatella dorsennata sp. nov.

(Pl. 13, fig. 18; Pl. 14, fig. 27-29)

?*Eucrassatella camura* (Pritchard) Cotton 1947, *Rec. S. Aust. Mus.* 8 (4): 662, Pl. 20, fig. 15, 16.

?*Eucrassatella kingiculoides* (Pritchard) Crespin 1950, *Proc. Roy. Soc. Vict.* 60: 153, Pl. 14, fig. 6.

ETYMOLOGY: Latin *dorsennus* a hunch back.

DESCRIPTION OF HOLOTYPE: P23042, right valve.

Valve rectangular, very elongate somewhat swollen, umbo depressed prosogyral situated 2/7 of the valve length from the anterior end. Anterior and posterior dorsal margins straight. Anterior dorsal margin sloping very steeply away from the umbo. Anterior margin convex passing into a gently convex ventral margin. Posterior margin slightly convex, obliquely truncating the posterior dorsal and ventral margins, posterior end of shell slightly attenuated.

Siphonal ridge present but weakly developed. Umbo very little produced, valve humped anteriorly at the base of the umbo.

Teeth. LAI obsolete. 3a very reduced in length but rather pointed. 3b very prominent, pointed and sloping anteriorly, 5b very thin. LPI long and prominent. Socket for 2 wide and deep. Resilifer wide, external ligament deeply impressed. Ventral margin of valve smooth.

Umbo ornamented with 20 ribs; these fade out 1·5 cm from the beak. Surface of valve ornamented with growth striae.

DESCRIPTION OF PARATYPE: P23043, left valve.

Similar in shape to the holotype. Siphonal ridge scarcely visible. The umbo is more depressed than in the type.

Teeth. LAII short, prominent; 2 rather short but pointed, 4b very thin and reduced, pointed at the ventral end.

Umbo ornamented with 22 ribs fading out 1·5 cm from the beak.

DIMENSIONS:

Holotype	P23042	L73	A22	H 53	T18	U51	$\frac{L}{U}$ 1·43	$\frac{L}{A}$ 3·3
Paratype	P23043	66	20	47	15	45	1·46	3·3
	P23044	68	19	47	16	46	1·48	3·6
	P23045	72	23	52	20	52	1·38	3·1

LOCATION OF TYPE: Nat. Mus. Vict., holotype P23042, Cudmore Collection. Paratype P23043, Cudmore Collection.

TYPE LOCALITY: Jemmy's Point Formation. Mississippi Ck Tramway Cutting F2 on GSV map, Bairnsdale 878332, Gippsland, Victoria.

AGE: Cheltenhamian.

STRATIGRAPHICAL DISTRIBUTION: Cheltenhamian (U. Mioc.)—Kalimnan (L. Plio.).

OCCURRENCE: Type locality, common.
Ritchie's Rd Cutting, W. side of Mississippi Ck, Fl on GSV map Bairnsdale 878329, common.
North Arm, 1 mile up the Arm, end of Hunter Rd.
No. 1 Bore, Kalimna Oil Co., Rigby Is., Lakes Entrance, 70 ft, CPC F3771.
Lower Shell Bed, Jemmy's Point, Lakes Entrance, uncommon.
Spring Ck, Minhamite, W. Victoria.
Tannery Bore, Hindmarsh, South Australia.
?Lakes Entrance Oil Shaft, 50 ft, 100 ft.
?Cowandilla Govt Bore No. 5, 485-507 ft, Adelaide, South Australia.

COMMENTS: The umbo is occasionally more pronounced than in the type particularly in specimens which have a strong anterior hump. North Arm specimens are smaller in size than the average specimens from Mississippi Ck. Comparing *Eucrassatella dorsennata* with *E. camura,* the former has an umbo which is more depressed and not flattened medially. *E. camura* does not possess the anterior hump and has a well marked siphonal ridge. Also 3b slopes posteriorly in *E. camura,* it is vertical or sloping anteriorly in *E. dorsennata*. Comparing *E. dorsennata* with *E. oblonga,* the former is more elongate and rectangular and does not have a high pointed umbo, *E. oblonga* does not have the anterior hump. The umbonal ribs are coarser in *E. dorsennata* and extend ventrally 0·5 cm more than in *E. oblonga.*

Some of the specimens from the Lakes Entrance Oil Shaft lack the typical anterior end of *E. dorsennata* and have a well marked siphonal ridge, the posterior end is also not as attenuated. Lack of sufficient material and precise depths prevents further interpretation.

Specimens from the Hindmarsh Bore compare well in shape with topotypes but have a larger number of finer ribs on the umbo.

MATERIAL: Type specimens, 32 topotypes. Ritchie's Cutting, 12 specimens.

North Arm, 9 specimens. Minhamite, 1 adult 6 juveniles. Tannery Bore, Hindmarsh, 17 specimens (mostly broken valves). Lakes Entrance Oil Shaft, 5 specimens.

Eucrassatella camura (Pritchard 1903)

(Pl. 13, fig. 12; Pl. 14, fig. 24; Pl. 15, fig. 33-34)

Crassatellites camurus Pritchard 1903, *Proc. Roy. Soc. Vict.* 15: 96, Pl. 64, fig. 5-9. Singleton 1945, ibid. 56: 256.

DESCRIPTION OF LECTOHOLOTYPE: MUGD 1762, right valve.

Valve small elongate subquadrate, umbo ¼ of the length of valve from anterior end. Anterior dorsal margin straight, posterior dorsal margin concave; anterior margin convex, ventral margin straight. Posterior margin straight abruptly truncating dorsal and ventral margins. Siphonal ridge well developed, somewhat curved towards posterior end.

Umbo prosogyral strongly incurved with a flattened area on the dorsal surface bounded by the siphonal ridge on the posterior side. This flattened area extends from the beak to about half way down the exterior of the valve.

Hinge plate short, wide and heavy about ¼ the height of the valve.

Teeth. LAI prominent, 3a small and pointed, 3b triangular, very wide at ventral end, very much projecting, sloping to the posterior end. 5b a very thin lamina. Pallial line entire. Internal ventral margin of valve smooth.

Umbo ornamented with about 21 concentric ribs fading out approx. 2·3 cm from the beak. Ribs are present on the posterior area fading out 9 mm from the beak. Surface of valve ornamented with growth striae only.

DESCRIPTION OF LECTOPARATYPE: MUGD 1761, left valve.

Valve quadrate slightly elongated. Umbo ²⁄₇ of valve length from the anterior end. Anterior and posterior dorsal margins slightly concave. Anterior margin convex merging into the slightly convex ventral margin. Siphonal ridge well developed.

Teeth. Anterior lateral AII short but well developed. Socket for 3a large for the size of the tooth. 2, 4b short, the ventral end projecting in 2, more so than in 4. Resilifer partly covered by a small plate just under the beak.

Umbo ornamented with 26 concentric ribs which fade out 2·5 cm from the beak.

DIMENSIONS:

Lectoholotype	MUGD 1762	L56	A12	H40	T13	U38	$\frac{L}{U}$1·47	$\frac{L}{A}$4·7
Lectoparatype	MUGD 1761	53	15	41	14	40	1·32	3·5
	P23046	59	16	43	15	42	1·40	3·7

Forsyth's Bank

LOCATION OF TYPE: Melb. Uni. Geol. Dept, lectoholotype MUGD 1762. Lectoparatype MUGD 1761. Paratypes MUGD 1763, 1764, 1765, 1766. All juveniles figured by Pritchard. Collected by G .B. Pritchard.

TYPE LOCALITY: (*vide* Singleton 1945, p. 256) Grange Burn Formation.

Grange Burn between Forsyth's and Henty's, Hamilton, W. Vict. is herein designated type locality. Age Kalimnan. As Singleton has noted already the type specimens MUGD 1761, 1762 appear to have the preservation more typical of the Kalimnan of Grange Burn. The coloration of MUGD 1765, 1766, and 1763 suggests that these came from Muddy Ck, MUGD 1764 could possibly have come from either locality. *Eucrassatella camura* is more common on Grange Burn, the species is relatively uncommon at MacDonald's Bank on Muddy Ck.

Stratigraphical Distribution: Cheltenhamian (U. Mio.)—Kalimnan (L. Plio.).

Occurrence: Forsyth's Grange Burn near Hamilton, W .Vict., common.
Between Forsyth's and Henty's, Grange Burn.
Pat's Gully, Grange Burn.
MacDonald's Bank, Muddy Ck, near Hamilton, W. Vict., rare.
Cheltenhamian Spring Ck, Minhamite, W. Vict., common.

Material: Type specimens. 21 specimens Grange Burn, 5 specimens (juvenile) MacDonald's Bank, 40 specimens Minhamite.

Comments: This is the smallest fossil species of *Eucrassatella*. It is recognized by the elongate shell and prominent umbo which is flattened on the crest and side. Specimens from Minhamite do not appear to differ at all from typical Kalimnan specimens.

Eucrassatella kingicoloides (Pritchard 1903)

(Pl. 14, fig. 23, 25-26)

Crassatellites kingicoloides Pritchard 1903, *Proc. Roy. Soc. Vict.* 15: 94, Pl. 13, fig. 1-3. Singleton 1945, ibid. 56: 257.

Description of Holotype: MUGD 1756, paired valves.

Shell equivalve, inequilateral, swollen below the umbo and somewhat flattened at the posterior end. Umbo prosogyral, prominent and slightly flattened, situated ⅖ the length of the shell from the anterior end. Anterior dorsal margin straight, posterior dorsal margin deeply concave, anterior margin strongly convex passing into a strongly convex ventral margin. Posterior dorsal and ventral margins attenuating, so that the posterior margin is much reduced.

Siphonal ridge prominent, strongly curved, flattening as it approaches the posterior end. Exterior of valve, just anterior to the siphonal ridge, somewhat flattened and even concave in the juvenile stages of the shell.

Hinge plate short, wide and thick about ⅓ umbo ventral diameter. Resilifer wide, ligament pit narrow.

Teeth. Right Valve. LAI small nearly obsolete, 3a narrow and thin, 3b large prominent sloping anteriorly, 5b minute, LPI large and elongated, slightly curved posteriorly. Left Valve. LAII small but prominent, finely striated on the dorsal side. 2 large sloping anteriorly, 4b long, the effective part of the tooth is the small projecting part at the ventral end, posterior laterals obsolete.

Umbo ornamented with 23 concentric ribs, these fade out 1·5 cm from the beak. Surface of valves ornamented with fine growth striae.

Dimensions:

Holotype	MUGD 1756	L69	A26	H54	T18	U54	$\frac{L}{U}$1·28	$\frac{L}{A}$2·7
	P4139	68	26	55	18	55	1·24	2·6
	P23047	81	28	68	21	67	1·21	2·9
	P23048	64	20	56	17	55	1·16	3·2
	P23049	76	28	58	20	57	1·33	2·7

LOCATION OF TYPE: Melb. Uni. Geol. Dept, MUGD 1756, collected by G. B. Pritchard.

TYPE LOCALITY: Jemmy's Point Formation. Jimmy's Point (=Jemmy's Point), Kalimna, Gippsland, Vict. Age Kalimnan.

MATERIAL: Type, 53 specimens, Jemmy's Point, Meringa Ck 6 specimens, Mississippi Ck 2 specimens.

STRATIGRAPHICAL DISTRIBUTION: Upper Cheltenhamian (U. Mioc.)-Kalimnan (L.Plio.).

OCCURRENCE:	Upper and Lower Beds, Jemmy's Point.
	Nyerimalang F7 GSV Map Bairnsdale.
Kalimnan	Bunga Ck Rd Cutting N. Side, bed (d) (Wilkins 1963, p. 44).
	Lake Tyers Hartland Military Sheet 002312.
	Meringa Ck, GSV Map Bairnsdale 86679.
Upper Cheltenhamian	Base of Cliff, i.e. at S.L.
	Mississippi Ck Tramway Cutting F2 GSV Map Bairnsdale 878332.
	Bunga Ck Rd Cutting N. Side, bed (b).
	Old Bunga Ck Crossing F10 GSV Map Parish of Colquhoun.
	Turn off to LED No. 2 Princes Highway road cutting.

COMMENTS: The shape of the species is rather variable. The umbos can be even more produced giving a greater posterior attenuation; however, the posterior end is usually not as attenuated as in the holotype, particularly in large adult specimens. Occasionally the umbones are orthogyral, e.g. P23050 from Mississippi Ck, and the shape of the shell approaches that of the genus *Hybolophus*. Woods (1922, p. 113) has compared *Hybolophus nelsoni* (Grzybowski) (= *clarensis* Woods) with *Eucrassatella kingicoloides*; however, *E. kingicoloides* generally lacks the prominent umbo-post-ventral depression characteristic of adult specimens of *Hybolophus* and the ventral margin is regularly convex, not having the posterior concavity in the ventral margin of specimens of *Hybolophus*. Occasionally, juvenile specimens of *E. kingicoloides* do tend to show a very slight concavity in the ventral margin and have a slight depression anterior to the siphonal ridge. The teeth of *E. kingicoloides* have more affinity with the type of *Eucrassatella* than with *Hybolophus antillarum* (Reeve) or *Hybolophus gibbosa* (Sowerby), the type of the genus.

Eucrassatella deltoides sp. nov.

(Pl. 13, fig. 15, 17; Pl. 15, fig. 30-31)

ETYMOLOGY: Greek = delta-shaped.

DESCRIPTION OF HOLOTYPE: P23051 right valve.

Valve trigonal, almost equilateral, umbo high and prominent, prosogyral, situated 5/12 of the valve length from the anterior end. Anterior and posterior dorsal margin straight sloping away equally from the top of the umbo. Convex anterior margin passing into a rather convex ventral margin. Posterior margin symmetrically truncating the posterior dorsal and ventral margins. Posterior end not attenuated.

Siphonal ridge well developed, and straight throughout its length.

Resilifer very wide and deep, external ligament pit deeply impressed.

Teeth. LAI obsolete, 3a obsolete, 3b prominent, pointed and sloping anteriorly, LPI long and prominent.

Distance between pallial line and anterior ventral margin of the valve is very wide, as in *E. kingicola*. Ventral margin of the valve smooth.

Umbo ornamented with 17 ribs which fade out 1cm from the beak. Surface of valve ornamented with growth striae.

DESCRIPTION OF PARATYPE: P23052 left valve.

The valve is more inequilateral than the type as the posterior end is more produced.

Teeth. LAII prominent, 2 short, very pointed, 4b considerably reduced.

Umbo ornamented with 20 ribs which fade out 1·5 cm from the beak.

DIMENSIONS:

Holotype	P23051	L74	A31	H66	T19	U66	$\frac{L}{U}$1·12	$\frac{L}{A}$ 2·4
Paratype	P23052	76	28	58	16	58	1·22	2·5
Paratype	F17002	75	30	66	18	66	1·14	2·5
	P23053	78	34	72	20	72	1·08	2·3
	P23054	68	29	64	19	64	1·06	2·3
	P23055	71	27	54	15	54	1·31	2·6

LOCATION OF TYPE: Nat. Mus. Vict., holotype P23051. collected by T. A. Darragh; paratype P23052. Tate Mus. Coll. Uni. Adel., paratype F17002.

TYPE LOCALITY: Formation, lateral equivalent of the Dutchman Coquinoid Limestone.

Hill's dragline water hole with windmill, ½ mile N. of Dutchman Lime Quarry, NE. of Dutchman, Flinders Is., Tas. Age M(?) Plio.(Post Kalimnan).

STRATIGRAPHIC RANGE: M(?) Pliocene.

OCCURRENCE: Type locality—common.

Dutchman Lime Quarry—common.

The dragline waterhole between the Memana Rd and Nelson Lagoon Drain, ¼ mile S. of the Cameron Inlet Rd, Flinders Is. (remanié deposit).

MATERIAL: Types and 48 topotypes; Quarry 11 specimens.

COMMENTS: Specimens from the Dutchman Lime Quarry are a little more elongate than typical specimens from the type locality. The quarry has been filled in, making collection of a large series difficult. Comparing *E. deltoides* with *E. eupontica,* the former is relatively equilateral, has a more convex ventral margin and a very prominent umbo. The distance between the pallial line and the anterior ventral margin is ⅓ as large in *E. deltoides* as in *E. eupontica*.

Eucrassatella memanae sp. nov.

(Pl. 12, fig. 2-3; Pl. 13, fig. 19-20)

ETYMOLOGY: Place name.

DESCRIPTION OF HOLOTYPE: P23056 right valve.

Valve elongate subtrigonal; umbo prominent, slightly prosogyral situated ⅓ of the valve length from the anterior end. Anterior dorsal margin straight, posterior dorsal margin straight, posterior dorsal margin concave. Anterior margin and ventral margin of equal convexity. The early growth lines show a slight change in curvature just anterior to the siphonal ridge. Posterior margin slightly convex obliquely truncating the posterior dorsal and ventral margins. Posterior end somewhat attenuated.

Siphonal ridge present but not well developed, curved posteriorly and fading out as it nears the ventral margin.

Teeth. 3a obsolete, 3b prominent, 5b much reduced, LPI very long, rather thin. Resilifer very wide, external ligament pit hardly differentiated from the resilifer.

Ventral margin of the valve smooth.

Umbo ornamented with 25 ribs which fade out 1·8 cm from the beak. Surface of the valve ornamented with coarse growth striae.

Description of Paratype: P23057 left valve.

Less elongate than the holotype, the posterior dorsal margin is not as convex. The siphonal ridge is relatively straight, anterior to the ridge is a depression extending almost to the ventral margin, the early growth lines have a prominent change in curvature at this position.

Teeth. LAII prominent, 2 well developed short and pointed, 4b much reduced.

Umbo ornamented with 29 ribs fading out 2·3 cm from the beak.

Dimensions:

Holotype	P23056	L89	A29	H69	T19	U68	$\frac{L}{U}$1·31	$\frac{L}{A}$3·1
Paratype	P23057	85	32	64	19	64	1·33	2·7
Paratype	F17003	87	29	64	18	63	1·38	3·0
	P23058	111	38	84	23	81	1·37	2·9
	P23059	92	28	67	20	66	1·40	3·3

Location of Types: Nat. Mus Vict., holotype P23056; paratype P23057. Tate Mus., Uni. Adel., paratype F17003. Collected by T. A. Darragh.

Type Locality: The dragline drain 1 mile N. of No. 1 Rd. Locality 1·5 mile E. of the N.-S. Rd which is 1 mile W. of Memana. At fifth weir E. from the N.-S. Rd, 300 yds W. of small bridge over drain, Memana, Flinders Is., Tasmania. Age U.(?) Pliocene.

Stratigraphic Range: U.(?) Pliocene.

Occurrence: Type locality common.

Material: Type specimens, 18 topotypes.

Comments: Small specimens of this species show a change in curvature of the ventral margin near the posterior end, some of the specimens have a concave margin at this point. The majority of the larger specimens however, have lost the concave margin and the ventral margin is regularly convex. This character is better developed in this species than in *E. kingicoloides*. *E. kingicoloides* has a more prominently attenuated posterior end and is more tumid than *E. memanae*.

Some of the specimens collected had the remains of the resilum still attached to the resilifer.

Eucrassatella sp. indet.

Specimens have been examined of species of *Eucrassatella* from Fishing Point, Lake Bullenmerri, the Mallee Bores, and Loxton. The specimens were either fragmentary or too poorly preserved to allow specific identification. The Mallee

Bore specimens were identified by F. Chapman as *Eucrassatella kingicoloides*. However, this identification is not considered to be correct.

Genus **Spissatella** Finlay 1926

(Pl. 15, fig. 35-37)

Spissatella Finlay 1926, *Trans. N.Z. Inst.* 56: 256. Type species (original designation): *Crassatella traill*i Hutton 1873.

Shell equivalve, sub-quadrangular, sub-equilateral to elongate, posterior end obliquely truncating the dorsal and ventral margins. Umbo prosogyral and pointed. Lunule and escutcheon impressed.

Siphonal ridge very prominent. Ornament of concentric ribs generally extending from the umbo to the ventral margin of the shell, occasionally confined to the umbo. Hinge plate short with a triangular resilifer extending from under the beak to the ventral margin of the hinge plate. Ligament pit very narrow.

Tooth formula $\frac{3a \quad 3b \quad 5b \quad LPI}{LAII \quad 2 \quad 4b}$. 3a is relatively well developed, as is LAII, socket for LAII prominent, 5b thin and much reduced, no corresponding socket in the left valve.

Pedal impression deeply impressed beneath LAII and posterior to the anterior muscle scar. Pallial line entire, well marked. Muscle scars sub-equal similar to those of *Eucrassatella*. Inner ventral margin generally smooth occasionally crenulated.

Spissatella maudensis (Pritchard 1903)

(Pl. 12, fig. 1-8; Pl. 13, fig. 11; Pl. 14, fig. 22)

Crassatellites maudensis Pritchard 1903, *Proc. Roy. Soc. Vict.* 15: 93, Pl. 14, fig. 2, 3. Singleton 1945, ibid. 56: 257.

Description of Holotype: MUGD 1759 right valve.

Valve elongate subquadrate. Umbo prosogyral, somewhat depressed, situated about ⅓ length of the valve from the anterior end, anterior and posterior dorsal margins straight and of equal declivity from the umbo, anterior margin strongly convex, ventral margin slightly convex, posterior margin abruptly truncating the ventral and dorsal margins.

Siphonal ridge well marked and straight, the siphonal area is slightly concave.

Hinge plate short, ⅓ height of the valve.

Teeth LAI short, not very prominent, 3a very small, 3b sloping anteriorly relatively thin but solid and prominent, 5b thin very little raised but rather long, LPI long prominent. Socket for 4b triangular, only slightly smaller than socket for 2.

Resilifer very wide and deep, extending from under the beak to the ventral edge of the hinge plate. It occupies all the space between 5b and LPI.

Ventral margin of the valve smooth.

Valve ornamented with prominent concentric ribs, these cover the entire surface of the juvenile portion of the valve, but fade out on the posterior area between the posterior dorsal edge and the siphonal ridge, and also fade out on the anterior end of the valve, being replaced by fine growth striae.

Description of Paratype: MUGD 1748 right valve.

Somewhat more elongated than the type and has a straight ventral margin. The valve shows signs of abrasion and has a polyzoan attached.

Description of Hypotype: P4173 left valve.

Valve very elongate, posterior dorsal and ventral margins somewhat attenuated at the posterior end.

Teeth. LAII short, not prominent, 2 rather thin but prominent, 4b similar to 2 but slightly thinner, LPII prominent. Resilifer large, external ligament pit much reduced. Socket for LPI separated from the resilifer by a thin lamellar extension of LPII.

Dimensions:

Holotype	MUGD	1759	L55	A20	H37	T13	U36	$\frac{L}{U}$1·53	$\frac{L}{A}$2·8	
Paratype	MUGD	1758	47	16	30	10	30	1·57	2·9	
Hypotype	P4173		60	17	34	12	34	1·76	3·5	A^d 23
	P23060		60	20	37	12	37	1·62	3·0	'Spring Ck'
	P23061		68	23	41	13	40	1·70	3·0	A^d 22

Location of Type: Melb. Uni. Geol. Dept, MUGD 1759; paratype MUGD 1758; collected by G. B. Pritchard. Nat. Mus. Vict., hypotype P4173, collected by the Geological Survey.

Type Locality: 'Lower and Middle bed of the Spring Creek series, or Bird Rock Bluff, near Geelong'. The types have no other label than 'Spring Creek'. *Vide* Singleton 1943, p. 257. The preservation of the holotype is similar to specimens labelled Ad 22 in the collection of the National Museum, the paratype is similar to specimens from Ad 23.

Stratigraphical Distribution: Janjukian (U. Oligo.-L. Mioc.?).

Occurrence: Bird Rock Bluff, Torquay.
Ledge Bird Rock Cliffs, Cudmore Collection, Ad 22, Ad 23—very common.
Junction Band at section, Whale Cave, Half Moon Bay beyond Bird Rock, Colliver Collection. Apparently the species is restricted to the strata beneath the Bird Rock Cap.
Lower Maude—the only specimen is a juvenile which may be referable to this species.
No. 1 Bore, Parish of Bumberah, 711 ft—a poorly preserved specimen possibly referable to this species. F5318 CPC.

Material: Type specimens 22. Torquay, Ad 22 2 specimens, Ad 23 6 specimens. Lower Beds Maude 1 specimen, juvenile. No. 1 Bore, Parish of Bumberah 1 specimen.

Comments: Specimens are generally a little more elongated than the type specimen as in the hypotype P4173. The posterior edge of the holotype is broken, approximately 1 mm of the valve is missing. Pritchard (1903, p. 94) indicated the type specimen as having dimensions 'antero-posterior diameter, 56 mm; umbo-ventral diameter, 36 mm'. This specimen is Pl. 14, fig. 3 (Pritchard 1903).

A pair of valves P23062-3 in the Pritchard Collection at the National Museum has approximately the measurements given by him and appears to be the specimen referred to in his original description (Pritchard 1903, p. 94).

Stratigraphical Use

So far *Eucrassatella* has not proved of value in detailed stratigraphical correlation, probably for a number of reasons. Firstly, *Eucrassatella* is rare from

Longfordian to Bairnsdalian because of lack of exposures of suitable facies. Thus the exact range of species is in doubt. Secondly, correlation from basin to basin is difficult because many species seem to be restricted geographically. Species such as *Eucrassatella eupontica* sp. nov. that are widespread are also long ranging. Thirdly, it is often difficult to collect the complete valves necessary for reliable identification because they tend to break near the posterior muscle scar.

The most useful species on present knowledge is *Eucrassatella kingicoloides* which first makes its appearance near the top of the Cheltenhamian in Gippsland and becomes very common in the Kalimnan. It takes the place of *E. dorsennata* which is common in the Cheltenhamian but rare in the Lower Kalimnan.

Acknowledgements

The author wishes to thank the following persons for their help in various aspects of this work: Mr E. D. Gill, National Museum of Victoria, and Dr C. M. Tattam, Melbourne University Geology Department, for arranging loans; Dr C. A. Fleming, Geological Survey of New Zealand, and Dr J. M. Gaillard, Muséum National d'Histoire Naturelle Paris, for sending photographs; Miss Cecily Finlay and Dr G. A. Thomas, Melbourne University Geology Department, for help and advice in photography; Professor I. A. Korobkov, Leningrad, for sending literature; Miss J. Hope Macpherson, National Museum of Victoria, for discussion on living species; and Dr O. P. Singleton, Melbourne University Geology Department, for reading the manuscript.

Bibliography

Cotton, B. C., 1947. Some Tertiary fossil molluscs from the Adelaidean stage (Pliocene) of South Australia. *Rec. S. Aust. Mus.* 8 (4): 653-670, Pl. 20-22.

Crespin, I., 1950. Some Tertiary pelecypoda from the Lakes Entrance Oil Shaft, Gippsland, Victoria. *Proc. Roy. Soc. Vict.* 60: 149-156, Pl. 14-17.

Davies, A. M., 1935. *Tertiary Faunas* I. Thomas Murby & Co., London.

Dennant, J., and Kitson, A. E., 1903. Catalogue of described species of fossils (except Bryozoa and Foraminifera) in the Cainozoic fauna of Victoria, South Australia and Tasmania. *Rec. Geol. Surv. Vict.* 1 (2): 89-147.

Finlay, H. J., 1926. New shells from New Zealand Tertiary beds, Pt 2. *Trans N.Z. Inst.* 56: 227-258, Pl. 55-60.

Finlay, H. J., and Marwick, J., 1937. The Wangoloan and associated molluscan faunas of Kaitangata—Green Island Subdivision. *N.Z. Geol. Surv. Pal. Bull.* 15.

————, ————, 1940. The Divisions of the Upper Cretaceous and Tertiary in New Zealand. *Trans. Roy. Soc. N.Z.* 70 (1): 77-135.

Iredale, T., 1924. Results from Roy Bell's molluscan collections. *Proc. Linn. Soc. N.S.W.* 49 (3): 179-278, Pl. 33-36.

Johnson, R. M., 1888. *Systematic Account of the Geology of Tasmania.* Government Printer, Hobart.

Korobrov, I. A., 1954. *Handbook on and Systematic Guide to the Tertiary Mollusca. Lamellibranchia.* State Scient-Tech. Publishing Agency Oil & Mineral Fuel Lit., Leningrad. (In Russian).

Lamarck, J. B. de, 1805. Suite des mémoires sur les fossiles des environs de Paris. *Ann. Mus. Hist. Nat. Paris* VI: 407-415.

————, 1818. Histoire naturelle des animaux sans vertèbres. 5, Paris.

Lamy, E., 1913. Note sur quelques coquilles du genre *Crassatella* déterminées par Lamarck. *Bull. Mus. Nat. Hist. Nat., Paris* 19 (2): 99-105.

————, 1917. Revision des Crassatellidae vivants du Muséum d'Histoire Naturelle de Paris. *Jour. de Conchyl.* 62 (4): 197-270, Pl. 6.

Ludbrook, N. H., 1955. The molluscan fauna of the Pliocene strata underlying the Adelaide Plains, Pt II—Pelecypoda. *Trans. Roy. Soc. S. Aust.* 78: 18-87, Pl. 1-6.

Macpherson, J. H., and Gabriel, C. J., 1962. *Marine Molluscs of Victoria.* Melbourne University Press.

May, W. L., 1919. A revised census of the Mollusca and Brachiopoda in the Table Cape Beds. *Proc. Roy. Soc. Tas.* for 1918: 101-107.

Mizuno, A., 1952. Descriptions of the Paleogene molluscs from Sakito, Nagasaki Prefecture, Japan. *Trans. Proc. Palaeont. Soc. Japan* 6: 185-193, Pl. 17.

Nagao, T., Palaeogene fossils of the Island of Kyushu, Japan, Pt 2. *Sci. Rep. Tohoku Imp. Univ. Ser. 2 (Geol.)* 12 (1): 11-140, Pl. 1-17.

Pritchard, G. B., 1896. A revision of the fossil fauna of the Table Cape Beds, Tasmania, with descriptions of new species. *Proc. Roy. Soc. Vict.* 8: 74-150, Pl. 2-4.

————, 1903. Contributions to the palaeontology of the Older Tertiary of Victoria. Lamellibranchs. Pt 3. ibid. 15: 87-103, Pl. 12-15.

Shuto, T., 1957. *Crassatellites* and *Venericardia* from the Miyazaki Group (Palaeontological study of the Miyazaki Group—IV). *Mem. Fac. Sci. Kyushu Univ. Ser. D Geology* VI (2): 69-89, Pl. 1.

Singleton, F. A., 1945. A catalogue of type and figures specimens of fossils in the Melbourne University Geology Department. *Proc. Roy. Soc. Vict.* 56: 229-284.

Stewart, R. B., 1930 Gabb's California Cretaceous and Tertiary type Lamellibranchs. *Acad. Nat. Sci. Philadelphia* Special Pub. 3.

Tenison Woods, J. E., 1876. On some Tertiary fossils from Table Cape. *Proc. Roy. Soc. Tas.* for 1875: 13-26, 3 Pl.

Verco, J. C., 1905. Notes on South Australian marine mollusca, with descriptions of new species, Pt II. *Trans. Roy. Soc. S. Aust.* 29: 166-172, Pl. 31.

————, 1907. Notes on South Australian marine mollusca with descriptions of new species, Pt VII. ibid. 31: 305-315, Pl. 29.

Wilkins, R. W. T., 1963. Relationships between the Mitchellian, Cheltenhamian and Kalimnan Stages in the Australian Tertiary. *Proc. Roy. Soc. Vict.* 76: 39-59.

Woods, H., in Bosworth, T. O., 1922. *Geology of Northwest Peru*, Macmillan, London.

Explanation of Plates

All photographs for illustration, except fig. 35-40, were taken by the author. Fig. 35-37 were supplied by Dr C. A. Fleming, Geological Survey of New Zealand, and fig. 38-40 by Dr J. M. Gaillard, Muséum National d'Histoire Naturelle Paris.

Plate 12

Fig. 1—*Spissatella maudensis* (Pritchard), MUGD. 1759, holotype internal right valve, Torquay, Vict., × 1.

Fig. 2—*Eucrassatella memanae* sp. nov., P23057, paratype internal left valve, Memana, Flinders Is., Tas., × 0·75.

Fig. 3—ditto, paratype external left valve, × 0·72.

Fig. 4—*Eucrassatella oblonga* (Tenison Woods), B27 Z199, type of *Crassatella aphrodina* Tenison Woods, upper bed Fossil Bluff near Wynyard, Tas., × 1.

Fig. 5—*Eucrassatella rosicollina* sp. nov., P23078, holotype external right valve, Moondara Farm, Mitchell R., Gippsland, Vict., × 0·73.

Fig. 6—*Eucrassatella rosicollina* sp. nov., P23079, paratype internal left valve, topotype, × 0·75.

Fig. 7—*Eucrassatella rosicollina* sp. nov., P23078, holotype internal right valve, locality as above, × 0·76.

Fig. 8—*Spissatella maudensis* (Pritchard), MUGD 1759, holotype external right valve, Torquay, Vict., × 1.

Fig. 9—*Eucrassatella oblonga* (Tenison Woods), B42 Z174, holotype external left valve, lower bed Fossil Bluff near Wynyard, Tas., × 0·75.

Fig. 10—ditto, holotype internal left valve, × 0·71.

Plate 13

Fig. 11—*Spissatella maudensis* (Pritchard), P4173, hypotype internal left valve, Ad 23, Torquay, Vict., × 0·95.

Fig. 12—*Eucrassatella camura* (Pritchard), MUGD 1761, lectoparatype internal left valve, Grange Burn near Forsyth's Bank, Hamilton, Vict., × 1.

Fig. 13—*Eucrassatella eupontica* sp. nov., P23074, holotype internal right valve, shell-bed above nodule bed Beaumaris, Vict., × 0·77.

Fig. 14—ditto, holotype external right valve, × 0·73.

Fig. 15—*Eucrassatella deltoides* sp. nov., P23052, paratype external left valve, E. side of Dutchman, Flinders Is., Tas., × 0·70.

Fig. 16—*Eucrassatella eupontica* sp. nov., P23075, paratype internal left valve, note remains of resilium, Warrambine Ck near Shelford, Vict., × 0·97.
Fig. 17—*Eucrassatella deltoides* sp. nov., P23051, holotype external right valve, E. side of Dutchman, Flinders Is., Tas., x 0·70.
Fig. 18—*Eucrassatella dorsennata* sp. nov., P23043, paratype internal left valve, Mississippi Ck tramway cutting near Lakes Entrance, Gippsland, Vict., × 0·92.
Fig. 19—*Eucrassatella memanae* sp. nov., P23056, holotype internal right valve, Memana, Flinders Is., Tas., × 0·74.
Fig. 20—ditto, holotype external right valve, × 0·72.

Plate 14

Fig. 21—*Eucrassatella oblonga* (Tenison Woods), P23073, hypotype internal right valve, lower bed Fossil Bluff near Wynyard, Tas., × 0·77.
Fig. 22—*Spissatella maudensis* (Pritchard), P4173, hypotype external left valve, Ad 23, Torquay, Vict., × 1.
Fig. 23—*Eucrassatella kingicoloides* (Pritchard), MUGD 1756, holotype external right valve, Jemmy's Point near Lakes Entrance, Gippsland, Vict., × 0·77.
Fig. 24—*Eucrassatella camura* (Pritchard), MUGD 1761, lectoparatype external left valve, Grange Burn near Forsyth's Bank, Hamilton, Vict., × 1.
Fig. 25—*Eucrassatella kingicoloides* (Pritchard), MUGD 1756, holotype internal right valve, Jemmy's Point near Lakes Entrance, Gippsland, Vict., × 0·79.
Fig. 26—ditto, holotype internal left valve, × 0·73.
Fig. 27—*Eucrassatella dorsennata* sp. nov., P23043, paratype external right valve, topotype, × 0·92.
Fig. 28—*Eucrassatella dorsennata* sp. nov., P23042, holotype internal right valve, Mississippi Ck near Lakes Entrance, Gippsland, Vict., × 1.
Fig. 29—ditto, holotype external right valve, × 0·92.

Plate 15

Fig. 30—*Eucrassatella deltoides* sp. nov., P23051, holotype internal right valve, E. side of Dutchman, Flinders Is., Tas., × 0·75.
Fig. 31—ditto, paratype internal left valve, × 0·73.
Fig. 32—*Eucrassatella eupontica* sp. nov., P23075, paratype external left valve, Warrambine Ck near Shelford, Vict., × 0·94.
Fig. 33—*Eucrassatella camura* (Pritchard), MUGD 1762, lectoholotype internal right valve, Grange Burn near Forsyth's Bank, Hamilton, Vict., × 1.
Fig. 34—ditto, lectoholotype external right valve, × 1.
Fig. 35—*Spissatella trailli* (Hutton), hypotype internal left valve, Awamoa, New Zealand, × 1.
Fig. 36—*Spissatella trailli* (Hutton), holotype internal right valve, Awamoa, New Zealand, × 1.
Fig. 37—ditto, holotype external right valve, × 1.
Fig. 38—*Eucrassatella kingicola* (Lamarck), holotype external left valve, note locality written on valve, King Is., Tas., × 0·75.
Fig. 39—ditto, holotype internal right valve, × 0·75.
Fig. 40—ditto, holotype internal left valve, × 0·75.


1
2
3
4
5
6
7
8
9
10


11


12


13


14

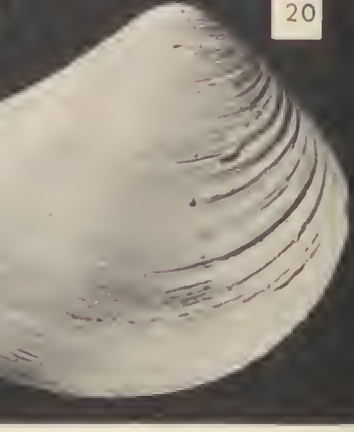

15


16

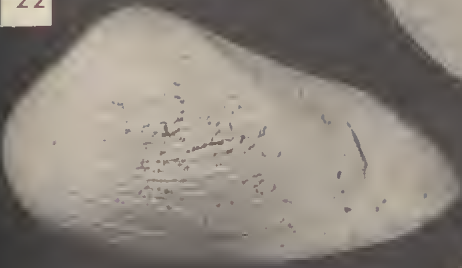

17


18


19


20


21


22


23


24


25

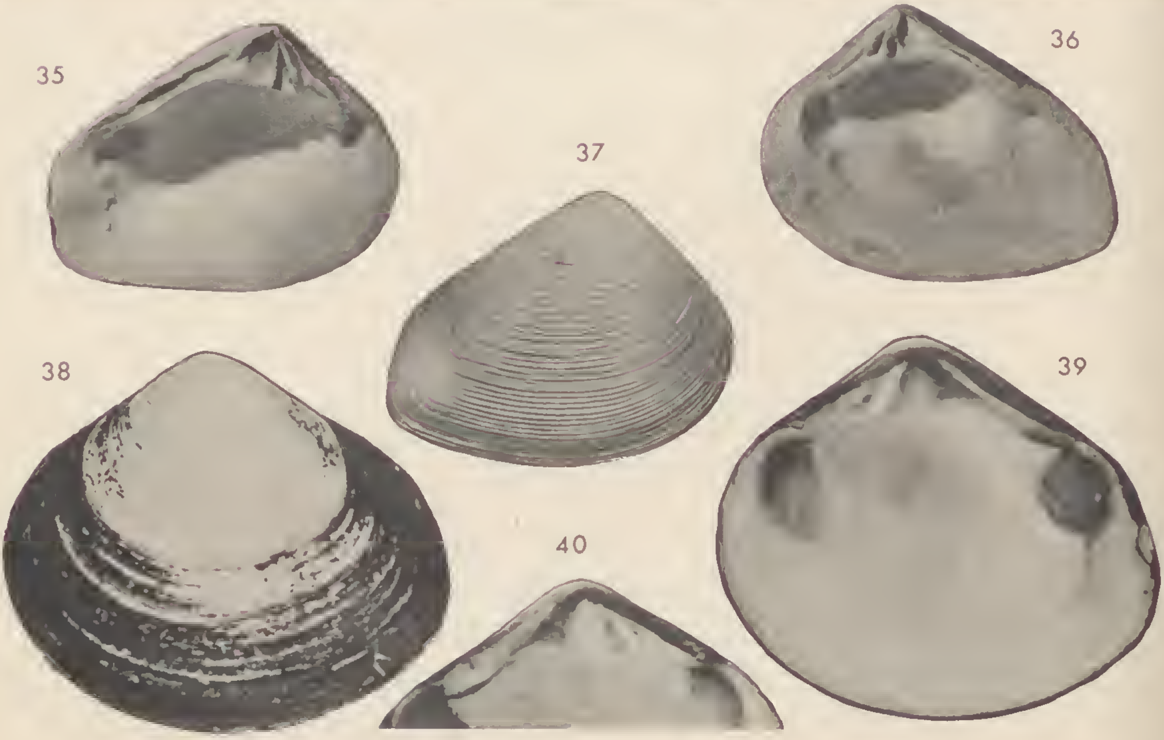

26


27


28


29


30
31
32
33
34


35
36
37
38
39
40

6

FOSSIL FUNGUS (*HYPOXYLON*) FROM TERTIARY BROWN COAL, YALLOURN, VICTORIA, AUSTRALIA

By J. H. Willis
National Herbarium, Melbourne
Edmund D. Gill
National Museum of Victoria

Occurrence (E.D.G.)

At Yallourn in E. Victoria, a seam of brown coal up to 170 ft thick has been extensively worked for power production, yielding at the same time a rich fossil flora. This formation is the Yallourn Seam, and the underclay is the Yallourn Clay (Thomas and Baragwanath 1949). The specimen now described was found near the base of the Yallourn Seam on a Museum collecting trip in 1950. In the section exposed, about 4 ft 6 in. of Yallourn Clay outcropped. The contact between the Yallourn Seam and the Yallourn Clay was approximately horizontal, but a narrow seam of brown coal a few feet from the top of the clay had a dip of about 5°, suggesting warping and some erosion of the clay before the brown coal of the Yallourn Seam was deposited. The top of the Yallourn seam is an erosion surface, but to a much greater degree. In the clay between the Yallourn Seam and the narrow band of brown coal referred to above was what appeared to be an animal burrow. This structure appeared in vertical section and was about 1 ft 10 in. deep; it began as a shaft about 4 in. in diameter and after a foot widened to a rounded cavity about 10 in. in diameter. The burrow was infilled with brown coal.

The base of the coal showed rapid change of facies. Lignitiferous clay (product of erosion of the underclay?) was followed by a layer rich in leaves and containing remains of *Agathis, Banksia, Araucaria*, and *Podocarpus,* then a resinous layer with leaves, a layer dominated by branches with bark still attached, and a layer with logs, wood, and fern stems. One stump in position of growth was noted in the base of the coal at the collecting site. There was not time to make a complete section, but 15 to 20 ft above the base of the coal was pollen coal 6 to 9 in. thick, followed by a layer rich in mummified leaves. The fossil fungus came from this layer. The plate shows the relationship of the fungus to the leaves.

The superficially close resemblance of the fossil specimen to a cluster of insect eggs prompted submission of a photograph to Dr W. E. China at the British Museum. He reported that, although the general appearance and position in clusters reminded one of hemipterous eggs, there was too much variation in size to admit such a possibility. Dr China showed the photograph to Mrs Balfour Browne who recognized the fungal nature of the objects and recommended that they be given to Mr J. H. Willis for description.

Age (E.D.G.)

The seams of coal have not yet been individually dated, and not even the groups of sediments have been adequately aged. Thomas and Baragwanath (1949, p. 43) and Gloe (1960) have provided the stratigraphy of the Latrobe Valley

Coal Measures, and so the relative ages of the seams are known. The general succession is:

Yallourn Group (youngest)	Yallourn Seam (fossil fungus) Yallourn Clay
Morwell Group	
Yinnar Group	
Narracan Group (oldest)	Associated with Older Basalt.

These Coal Measures probably range in age from Eocene to Oligocene. The flora found at Yallourn occurs underneath Miocene marine rocks in a number of places, and the Older Basalts are older than the Miocene Nunawading Terrain (Gill 1964). Until the needed detailed work is done, the best dating that can be given for the fossil fungus is Oligocene.

Identification and discussion (J.H.W.)

A brief inspection was enough to show remarkably close external resemblance to the living *Hypoxylon truncatum* (Schweinitz ex Fries) J. H. Miller (1932). Both have erumpent but confluent, subglobular, black and carbonous perithecia, each 0·5-1·3 mm in diameter, with flat apical annular disc (0·3-0·5 mm wide) from the centre of which projects a minute, conical, nipple-like ostiole. Ascospores removed from the fossil perithecia proved to be identical with those of living *H. truncatum* collected from dead bark in the Dandenong Ranges, viz. 9·5-12·5 × 4-5·5 mic., irregularly elliptic (or bean-shaped), dull brown, with a distinct colourless longitudinal furrow or germ pore.

Botanists are understandably cautious in applying names of living plant species to fossils millions of years old, but in the present instance the writer has very little hesitation in identifying the Yallourn *Hypoxylon* as *H. truncatum* (syn. *H. annulatum* Mont.). According to J. H. Miller (1961), *H. truncatum* occurs on many kinds of dicotyledonous trees, and it ranges almost throughout warmer regions of the world, e.g. Africa, Australia, India, Malaya, China, Japan, Hawaii, southern parts of U.S.A., Mexico, West Indies, tropical and subtropical South America; so it is hardly surprising that such a very widespread modern fungus should also have a long geological history.

Only one species of *Hypoxylon* in the section Annulata seems now to occur in Europe, viz. *H. michelianum* Ces. & De Not. which is known from Italy, apparently always on *Laurus nobilis*. It is closely related to *H. truncatum*, differing in the consistently smaller annular discs (0·1-0·3 mm wide). But brown coal deposits of Limburg province, Holland, have provided a fossil *Hypoxylon* published by R. Kräusel (1961) under the name *Sphaerites areolatus* (G. Fresenius & H. Meyer) A. Meschinelli, with the remark (translated from German): 'Even with knowledge of the spores, it could be impossible to refer such fossils to a definite recent genus. We must therefore designate them as a "form-genus"'. Kräusel describes the perithecia ('pustules') as 0·3-0·8 mm wide, and spores 12-18 mic. long. His excellent photograph is almost a facsimile of *H. annulatum* (= *H. truncatum*) as illustrated by C. G. Lloyd (1925), and were it not for the slightly longer spores, one would scarcely hesitate to refer the Netherlands fossil also to this variable species of pan-tropical distribution.

From the Yallourn brown coal, H. T. Clifford and Isabel C. Cookson (1953) described a fossil moss capsule, while the latter author (1947) has also described four new genera and eight new species of micro-fungi from the Latrobe valley brown coals, most occurring on mummified leaves of *Oleinites willisii* (family Oleaceae). In the same paper, Cookson (1947) presents two other new genera and four new species from Tertiary deposits on the Aire River coast (Victoria), Kiandra (N.S.W.), Ohai (N.Z.) and Kerguelen Island. All these fungi are members of the ascomycetous order *Hemisphaeriales,* of which many living representatives are components of the familiar 'sooty-mould' associations on foliage. Concerning 'larger' fungi, the writer is not aware that any fossil species has been recorded in Australia before the discovery of the specimen herein described.

Acknowledgements

The authors are grateful to Dr Isabel Cookson, University of Melbourne, who made microscopic preparations of the brittle fossil fruiting structures, and to Mr Gordon Beaton of Camperdown who accurately measured and drew the spores at a magnification of 4500.

References

Clifford, H. T., and Cookson, Isabel C., 1953. *Muscites yallournensis,* a fossil moss capsule from Yallourn, Victoria. *Bryologist* 56: 53-55.

Cookson, Isabel C., 1947. Fossil fungi from Tertiary deposits in the Southern Hemisphere, Pt 1. *Proc. Linn. Soc. N.S.W.* 72: 207-214.

Gill, E. D., 1964. Rocks contiguous with the basaltic cuirass of Western Victoria. *Proc. Roy. Soc. Vict.* 77: 331-355.

Gloe, C. S., 1960. The geology of the Latrobe Valley coalfield. *Proc. Austr. Inst. Min. Metall.* 194: 57-125.

Kräusel, R., 1961. Ein Ascomycet aus der holländischen Braunkohle. *Senck. Leth.* 42: 43-48.

Lloyd, C. G., 1925. *Mycological Notes* 7: 331, fig. 3145.

Miller, J. H., 1961. Monograph of the world species of Hypoxylon, p. 95-99 (posthumous publication).

Thomas, D. E., and Baragwanath, W., 1949. Geology of the brown coals of Victoria. Pt 1. *Min. & Geol. J. (Vict.):* 3(6): 28-55.

Explanation of Plate

Plate 16

Hypoxylon truncatum, a fossil colony on bark and among leaves from near base of the Yallourn Seam, Yallourn brown coal mine (open cut), Victoria. Much enlarged. National Museum of Victoria reg. no. P22651. Age: Probably Oligocene.

7

GEOMORPHIC FORMS AND PROCESSES IN THE HIGHLANDS OF EASTERN VICTORIA

By John A. Talent
Geological Survey of Victoria

Abstract

Rock rivers and stepping of valleys in association with boulder cascades on the highlands about the headwaters of the Indi and Buchan R. are described and attributed to Pleistocene periglaciation; a glacial origin for large amphitheatre-like valley heads developed in this region is discounted. Fossil solifluction deposits at Mt Hotham are described. Attention is drawn to dominant lithologic and structural controls in the stepping of upland valleys and slopes formerly thought to be evidence for Pleistocene glaciation or periglaciation.

Introduction

This paper is concerned with the question of glaciation and periglaciation of the Victorian highlands; it is essentially a miscellany, a by-product of structural and stratigraphic investigations, and does not attempt to review the entire question. Its purpose is rather to describe and account for previously unrecorded rock rivers developed on rhyodacites on peaks about The Cobberas and Mt Wombargo at the head of the Indi and Buchan R.; to describe and account for the previously undescribed stepping of valley heads occurring in association with boulder cascades in the same area; to discuss the problem of amphitheatre-like valley heads on The Cobberas and adjacent rhyodacite peaks; to draw attention to the presence of appreciable fossil solifluction deposits and, following on from this, to assess generally the significance of stepping of valleys and slopes as evidence for Pleistocene glaciation or periglaciation.

The reader interested in prior literature on this question in Victoria is referred to the works of Carr and Costin (1955), Costin (1957), and Beavis (1959). Relevant works on the glaciation and periglaciation of adjacent parts of New South Wales are those by Jennings (1956), Browne (1957), Browne and Vallance (1963), and Galloway (1963). The older literature and an appreciation of the differing viewpoints can be garnered from the literature cited in these works. Broader aspects of the ecology, climate, soils, and geology of the upland regions of E. Victoria have been discussed in the High Plains Symposium of the Royal Society of Victoria (1962). The present investigation has not been concerned with the potency of contemporary mechanical processes about and above the timber line. Frost spalling still occurs on the highlands (Pl. 18, fig. 5), and in many localities is contributing to the rapid opening up of cleavage, bedding and joint planes and the prising out of shales and slatey rocks (Pl. 18, fig. 6). Needle ice is important in keeping disturbed upland soils in a state of disaggregation. Snow patch erosion is so restricted in extent and limited to such small areas that, taken alone, it cannot be regarded as a significant contemporary periglacial phenomenon.

The highlands of E. Victoria consist of scattered remnants of formerly more extensive gently undulating to vaguely stepped upland surfaces surrounded by

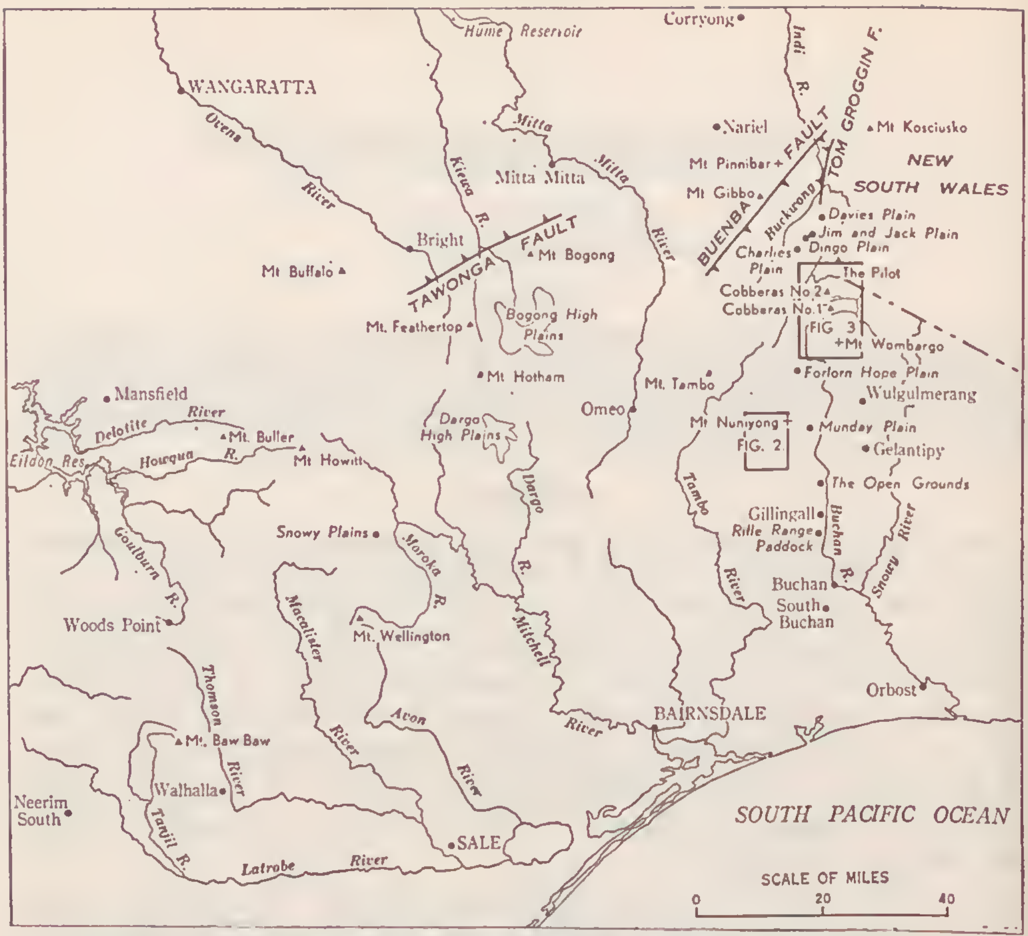


FIG. 1—Locality plan of E. Victoria including localities cited in the text, and location of Fig. 2 and 3.

strongly dissected, steeply sloping country with sharp interfluves and V-shaped valleys. They have developed on a wide variety of sedimentary and igneous formations (Neilson 1962), the most prominent of the upland surfaces bevelling their summits being remnants of formerly widespread Tertiary basalts filling depressions in the old Lower Tertiary surface. There are scarps obviously connected with differential erosion, e.g. Mt Pinnibar, and monadnocks projecting above areas of relatively planar surface, e.g. The Cobberas. There is some complication from Cainozoic faulting and warping connected with the Kosciusko Uplift, though it is only the larger faults such as the Buenba and Tawonga faults, or recent faults such as the Tom Groggin Fault, which attract attention (Fig. 1). The upland surfaces bevel the high parts of E. Victoria more or less regardless of the distribution of the main belts of rocks. Though from afar they may appear to be dismembered parts of a former plain or peneplain or series of peneplains, a closer inspection reveals that the problem of these old surfaces is not so simple because the uplands

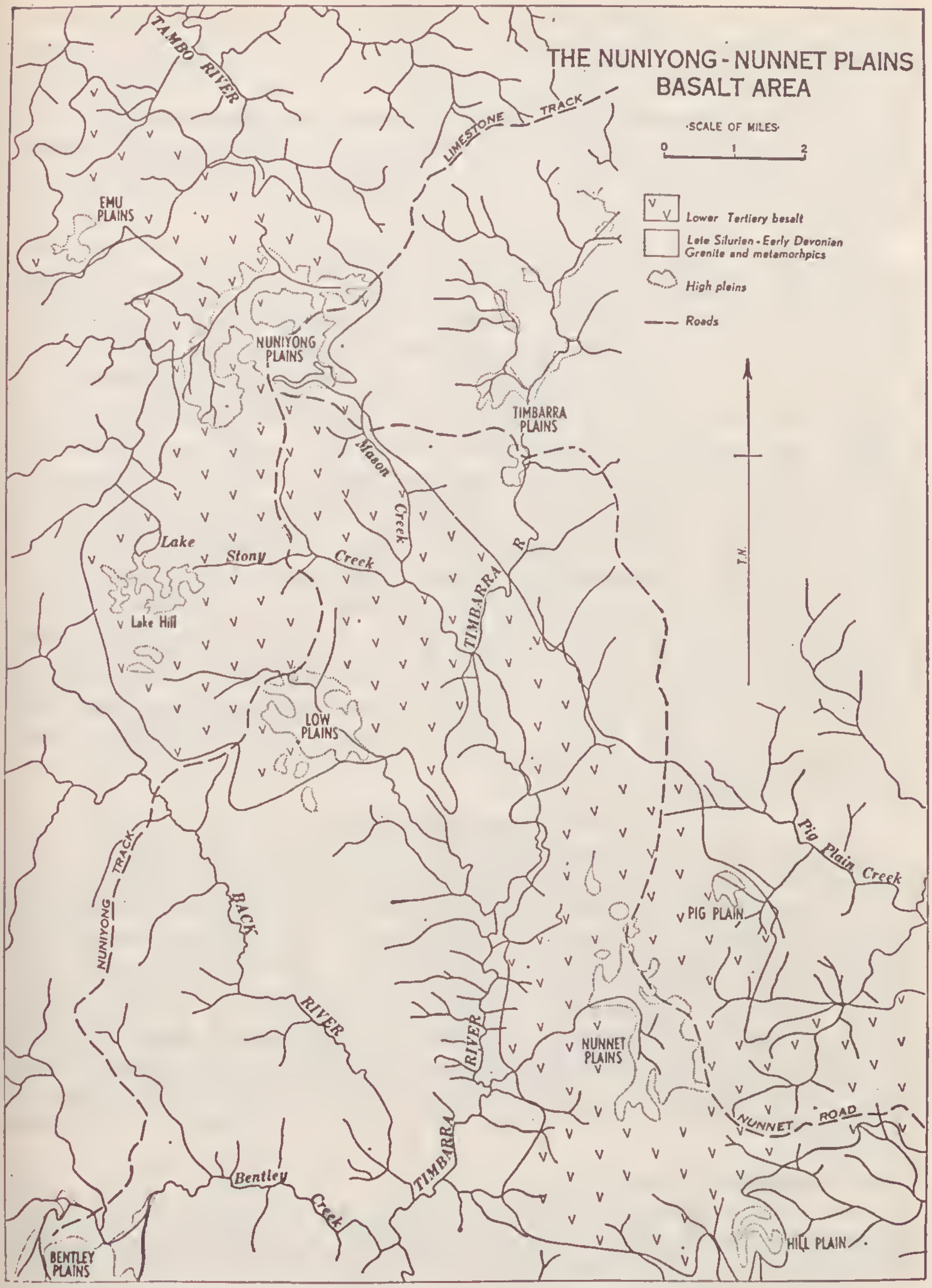


FIG. 2—The Nuniyong-Nunnet plains Lower Tertiary basalt area to show the various localities mentioned in the text (from unpublished geological plan Omeo 1 mile sheet by J. A. Talent, P. E. Bock, K. J. Reed, and R. C. Glenie).

resolve into a series of 'levels' tending to defy correlation over extended distances. There is little or no truly flat surface—much of a given area of upland, e.g. Nuniyong-Nunnet Plains (Fig. 2), will be found to slope more than gently with the upland flats at different levels merging into one another by sloping land with declivities of the order of 400-800 ft per mile. The problem of these old surfaces in the Victorian highlands is a fascinating one awaiting detailed study. Attention is drawn to them here purely as background to the discussion, particularly of the significance of stepping of valleys and slopes to follow later in this paper.

In contrast with the adjacent Kosciusko massif in New South Wales, there are no known moraine-dammed or glacially scoured lakes in the Victorian highlands. Natural bodies of water are rare; the majority of these are shallow stretches of open water an acre or two in extent associated with soligenous bogs, e.g. Moss Bed Lake, Lake Kelly, and the lakelets on Forlorn Hope and Munday's plains. Lake Nigothoruk or Tali Karng near Mt Wellington is unique for the Victorian highlands, being due to a large rockfall of Upper Devonian rhyolites (Howitt 1891; Howitt, Lucas, and Dendy 1891; Thiele 1905). Lake Omeo, in contrast, is due to Quaternary faulting. There are a few examples of natural ponds associated with the Lower Tertiary basalts. The most conspicuous of these is the nameless lake and its satellite on the top of mesa-like Lake Hill between Nuniyong and Low Plains. The lake is shallow, 2′-2′6″ in depth, about 390 yds along its longest axis and is situated on a near planar surface with shallow basaltic soils and frequent outcrops of basalt. A meteoritic origin can be discounted by the near planar surface of its immediate surroundings and the absence of an elevated rim; a glacial origin can be discounted by the absence of moraine or other evidence of glaciation in the region. It appears to be a primary depression of the old Lower Tertiary basaltic surface, similar to those at Wulgulmerang and on the Monaro Tableland in S. New South Wales, e.g. Lake Maffra. It recalls some of the lakes associated with the Newer Volcanics of the Western District of Victoria. Trench formations, almost exclusively the gamma-type (McElroy 1952) can be found on many of the natural clearings on the highlands of E. Victoria.

Rock Rivers or Block Streams

Carr and Costin (1955) and Costin (1957) have already mentioned rock rivers in association with the basalts of the Bogong and Dargo High plains. Jennings (1956) has described rock rivers from near the head of the Tumut R. in New South Wales and has invoked periglaciation for their genesis. His description corresponds so closely to the Victorian basaltic examples that these will not be discussed further here beyond mentioning that they are widespread on steep slopes around basalt residuals in the Victorian highlands and may be spectacular, e.g. at Mt Tabletop near Mt Hotham. There appears to be no published record of rock rivers developed from a rock type in Victoria other than basalt. For this reason an account is now given of spectacular rock rivers developed on rhyodacites about The Cobberas and Mt Wombargo, occurring well above the lower limits for development of basaltic rock rivers.

1. MT WOMBARGO AND BIG HILL

Great rivers of rhyodacite boulders are common on the N. and W. slopes of Mt Wombargo (5,400 ft) and the somewhat smaller but morphologically similar Big Hill (5,250 ft), extending down to altitudes of about 3,900 ft (Pl 21; Pl. 19, fig.

1-4, 6). The distribution of these is shown on Cobberas one mile geological map (Talent, Bock, and Glenie 1964). On Mt Wombargo the rock rivers consist at the surface of blocks varying in size from 6 in. to 2 ft with larger blocks up to 8 × 4 × 3 ft, i.e. several tons in weight; on rare occasions blocks of greater size occur. The rock rivers extend for as much as 600 yds downslope and have a maximum unvegetated or poorly vegetated width of 53 yds with greater widths at the junction of tributaries; in general the unvegetated central portion is 12-20 yds in width. In all cases some allowance must be made for a greater lateral extent now masked by soil and vegetation; this cover hampers interpretation for much of the area.

The average slope is of the order of 26° with slopes down to 20°. Flatter slopes of the order of 4½-5° occur at the head of the surveyed rock river (Fig. 4) above the surveyed tract where it starts to dissipate among a series of bluffs of rhyodacite 15-20 ft in height. Flatter slopes occur where rock rivers run out onto flatter ground, e.g. along the NW. side of Mt Wombargo (Pl. 21).

The rock rivers may be distinctly convex in transverse profile, but in general they occupy a slight depression on the hillside. The main body of most of these rock rivers remains unvegetated or with occasional trees growing among the boulders. There may be areas where soil is not far removed from the surface and others where the soil occurs in a pocket in the surface of the rock river. On flatter areas of descent there is an increased tendency to carpeting with soil and vegetation. Each river is associated with a seepage or even an appreciable flow of water issuing from its foot; rarely is there any evidence of surface flow of water on a rock river and where there is it is very localized and in no way alters the impression of all drainage being beneath the boulder accumulation. The rock rivers themselves have the rough morphology of surface drainage, being joined in small measure by tributaries and having a tendency to disintegrate towards their head into a series of feeders; their relationship to surface drainage will be obvious from a glance at Pl. 21.

A closer inspection reveals that the surfaces of the boulders are fretted to a uniform degree from top to bottom of the rock rivers; the quartz phenocrysts now project above the surfaces of the boulders. The undisturbed growth of trees occurring often in midstream and the apparent lateral extension of the same material into completely vegetated areas on either side reinforces this picture of complete immobility under present climatic conditions. It seems they have been at a standstill for a long time, in view of the appreciable advance of soil and vegetation. One may argue that the centre of such a rock river has had its fines removed by the streamlet associated with it. Surface examination and shallow excavation, however, indicates there is very little fine material in the range ½-3 in. in these accumulations. This seems to indicate that there was no great comminution of the joint blocks once they were freed and that the remarkable proportion of open space is some sort of reflection of the original condition of the mass; this can be verified only by deep excavation. Excavation of the related terraced accumulations (see below) supports considerable primary open space.

The very great thickness of these rocks and the great amount of open space is incompatible with generation in situ. The size and morphology of the boulders argues against derivation from pre-glacial weathering mantles. The most significant facts are that the morphology resembles a stream, running water occurs beneath each rock river and they originate in many cases at a series of low bluffs, indicating that the blocks were derived from the bluffs where, presumably, they were wedged out by vigorous frost action. The massive rhyodacite, impervious except along well spaced joint planes, was eminently suitable as a source of large blocks. They were most probably moved downslope from the bluffs by frost heave, becoming gradually incorporated in a rock 'glacier' with its interstices filled with ice from water from the subjacent spring. In their lack of interstitial filling these rock rivers are similar to the rock glaciers described by S. R. Capps (1910) from Alaska where, too, the interstital filling, if present at all, consists only of ice. The 26° slope of the Wombargo and Big Hill rock rivers is rather higher than the 9-18° slope of the Alaska rock glaciers. Unlike the Alaskan rock glaciers, they do not seem to have been the dying stages of a glaciation but rather the climax of periglaciation reached at this locality. Had they been connected with the dying stage of glaciation there should be a few cirques and moraines in the area.

When active, these rock rivers were comparable in many respects with forms from N. Canada, described by J. B. Tyrrell (1910), in which a mass of ice fills the interstices of a talus, the ice being from the freezing of waters from a subjacent spring; the resultant 'chrystocrene' has a movement intermediate between a creeping talus and a rock glacier.

2. Cobberas No. 1

The Middle Peak on Cobberas No. 1 (Pl. 18, fig. 3, 4) rises above large joint blocks stretching out downslope into the amphitheatre head of Towanga Ck. But the blocks are almost all discoloured, weatherbeaten, mottled by lichens and intergrown with vegetation if not in part buried beneath soil cover. In spite of the strong columnar jointing of Middle Peak there is little evidence of recent fall out around the E. face of the bluff (Pl. 18, fig. 3) and no evidence of injury to trees. The overall impression is of a condition undisturbed for a long time with more leisurely weathering in situ. Here and there down the slope in front (E.) of Middle Peak there is the impression of a rock river, the whole slope being significantly around 27°, comparable to the rock rivers on Mt Wombargo, but the cover of vegetation and soil leaves some uncertainty at first inspection. It is my impression there is an intermittently buried rock river descending into the amphitheatre from Middle Peak. It differs from the examples at Mt Wombargo in having a larger bluff of more spectacularly jointed rhyodacite as source of the blocks.

The most impressive rock rivers in the Cobberas No. 1 amphitheatre descend from the Cleft Peak right down to Towanga Ck and are there well exposed along the sides of the creek (Pl. 19, fig. 4). Their definite river-like orientation downslope, the lack of filling of interstices, the lack of clays and indeed their virtual lack of boulders under 2 in., as well as the dominance of boulders 6 in. or more in size, show their identity in all essential respects with the rock rivers at Mt Wombargo. They, therefore, do not have the morphology of moraines, but again are regarded as formed by chrystocrenes. The rock rivers have continued onto the flatter slopes of the amphitheatre, presumably under the head of rock and ice behind them. They tend, therefore, to merge with the deposits that are associated with stepping of the lower parts of the amphitheatre (see below).

Stepping of Valleys in association with Boulder Cascades

The head of Moscow Ck between the Cleft Peak and Moscow Peak is a deep but comparatively broad valley head with a broad saddle separating it from the head of Bullies Ck (Fig. 3). The terraces within it are of varying shapes (Pl. 23),

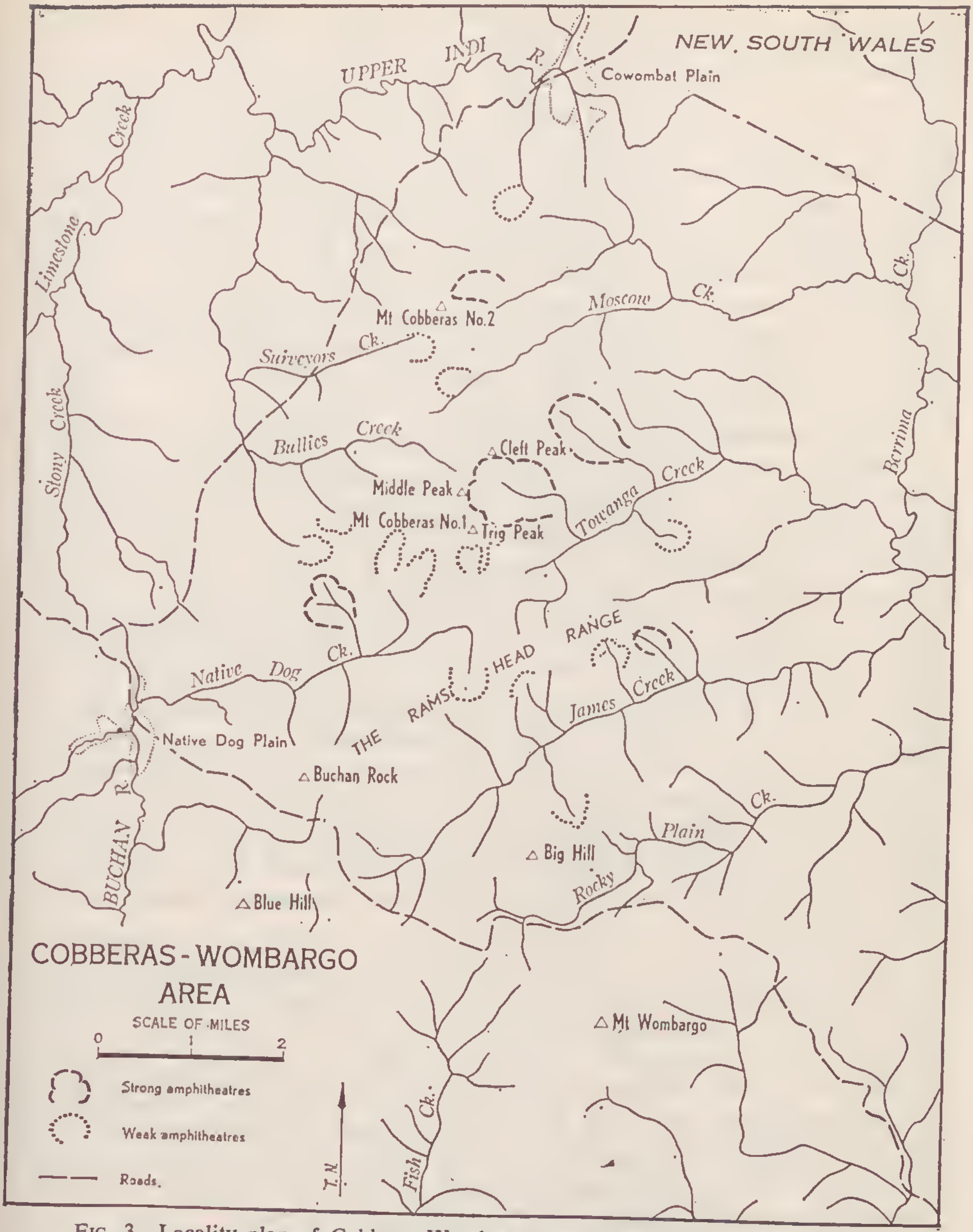


FIG. 3—Locality plan of Cobberas-Wombargo area showing location of strong and weak amphitheatres. Rock rivers in this area are shown on geological plan Cobberas 1 mile sheet (Talent, Glenie, and Bock 1964) and in part on Pl. 23.

occurring as a series related to the principal springs and rivulets. They have gently undulating to flat surfaces sloping at declivities around 1 in 10, but as gentle as 1 in 23, for 50-120 yds, followed by an abrupt steepening to a slope of 1 in 2·5 or 3 (cf. Fig. 4) on each rampart. At some point on this rampart the stream will be found to descend a vertical distance of 7-25 ft through and over a heterogeneous mass of tumbled, well weathered boulders with shrubs and small trees growing among them. The rampart surfaces away from the watercourses are noticeably more rocky than the adjacent terrace surfaces, though they too may be almost completely covered by soil, with only occasional boulders appearing among the cover of snow grass, shrubs, and patches of sphagnum moss with its associated flora. The foot of the rampart or the back of the next terrace tends to be occupied by a boggy area with sphagnum and running water from springs. Running water may cover a comparatively broad sheet of the terrace surface, be restricted to defined and sometimes incised channels, or may flow or seep between the boulders beneath the surface of the terrace. Similar terracing of a tributary of Native Dog Ck is figured (Pl. 22, fig. 1).

The amphitheatre-like head of Towanga Ck between the peaks of Cobberas No. 1 (described above in the discussion of the Cobberas amphitheatres) is 1½ miles across from ridge to ridge at its widest. Except for cliffs high on its slopes and on a peak at the mouth of the amphitheatre, the topography down in the amphitheatre and on its slopes is subdued but complex; the drainage through and over its surface is intricate. The surface cover of the amphitheatre is complex, including rock fall, talus and rock rivers. Terraces similar to those in Moscow Ck occur on small watercourses on either side of the main drainage, but the best terracing occurs in the vicinity of the main stream, or more accurately, along the principal floor of drainage, for water seeps and flows in intricate fashion over a wide area in the centre of the amphitheatre. The terraces in the centre of the amphitheatre (Fig. 4) differ from those in Moscow Ck by their comparative isolation from the amphitheatre walls—they come and go across the principal directions of drainage. Otherwise they are very similar, with a benched portion of boggy to tussocky ground with patches of heath, snow grass and sphagnum, and irregular patches of water among the vegetation and tending to be separated from one another by ramparts of jumbled blocks averaging a foot in diameter, but with large ones up to an observed 6 × 6 × 4 ft. In all cases noted, water was issuing from the foot of the rampart. The boulders or blocks are strongly weathered on their exposed surface; many are mottled with lichens.

A notable exception to the general pattern is a low crescent-shaped terrace about 16 yds long (across the slope), and 14 yds in maximum width in the downslope direction (Pl. 19, fig. 5). It is located about the middle of the amphitheatre at the foot of a normal larger terrace with a rampart composed of a jumble of lichen-mottled rhyodacite boulders; otherwise it is surrounded by bog. It contrasts with other terraces in being raised very little above the surrounding bog, and in bearing no soil on its surface among the boulders. It contrasts with the rampart behind it by its lack of surface vegetation, except for a few shrubs along its downslope boundary with the bog, and in the lack of lichen growth on its boulders. A casual inspection suggests relative youth compared with other terraces associated with boulder cascades in the Cobberas area.

It is composed at the surface of boulders 8 in. to 1 ft in diameter with some up to 2 ft across. Excavation in March 1963 showed that similar boulders with associated smaller boulders occur continuously down to the level of the water and

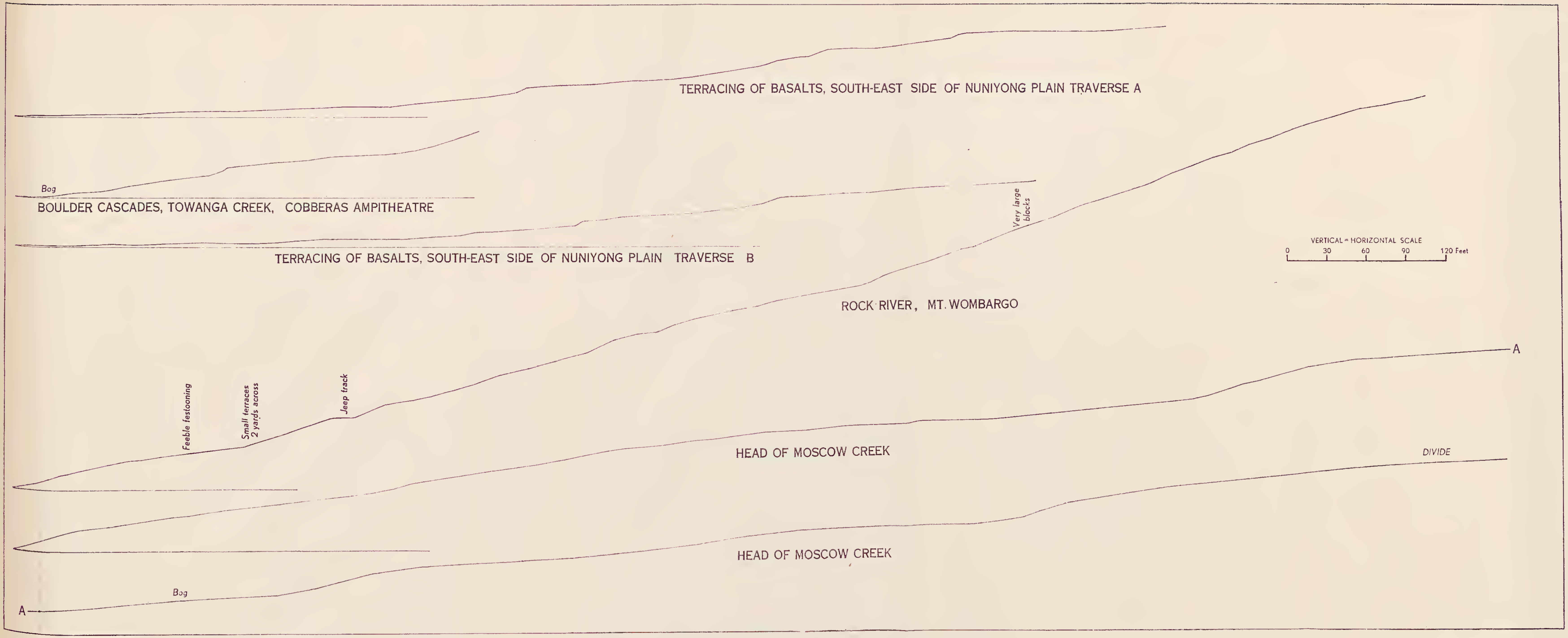


Fig. 4—Abney level profiles of terracing of basalts on the SE. side of Nuniyong Plain (cf. Pl. 17, fig. 1 and 2), typical of the Lower Tertiary basalt residuals of E. Victoria; a rock river on the NW. side of Mt. Wombargo (cf. Pl. 20, fig. 1-3, 6); stepping with boulder cascades on Towanga Ck near the centre of the Cobberas No. 1 amphitheatre, the bare terrace, Pl. 20, fig. 5, being beside the bog at the start of the traverse; a traverse up the head of Moscow Ck to the Great Divide through the terraces with boulder cascades (cf. Pl. 23 where these are emphasized by snow)—the terraces are more impressive in the field than they appear on the traverse.

mud 2 ft below the surface and for at least another foot below that. When the surface boulders are examined closely it is seen that, in spite of the absence of lichens, their surfaces are well fretted leaving the quartz phenocrysts protruding considerably above the surface. The quartz phenocrysts protrude less in boulders beneath the surface; boulders beneath the water table are smooth. The degree of fretting of such resistant rock indicates a considerable antiquity for the surface of the accumulation, with no significant disturbance of the accumulation since the fretting commenced. The absence of vegetation from most of this terrace, therefore, can have no temporal significance. The absence of lichens is not completely understood. There is a strong flow of water beneath the surface of the accumulation. It may be that water flows over the surface for a sufficient period during the year to prevent lichen growth, much as in the case of boulders in the beds of intermittent streams. Such a flushing process for part of the year may explain the lack of soil on the surface of the accumulation. The absence of various small grades from the accumulation indicates the original accumulation was probably essentially free from these grades. It must, therefore, have had a lot of vacant space or have been bimodal with boulders and blocks in a fine matrix.

Evidence for comparative antiquity of the boulder rampart terraces is indicated by the fretting of particularly resistant rhyodacite boulders on their exposed surfaces compared with boulders beneath the surface, the maturity of soils in the better drained portions of terraces, and the near complete cover of vegetation, including trees growing on the ramparts. The fretting of only the outer surfaces of boulders on the ramparts shows these have not been disturbed for a long period. In other words, the configuration of the terraces was achieved sometime in the past and is not connected with contemporary downslope movement of waste.

The contemporary flow of the streams in the valley heads is powerless to move the large blocks over and around which they flow in descending the ramparts of each terrace. The ramparts may include blocks of the order of 1 or 2 tons in weight. I cannot conceive of any stream so near its head ever having sufficient flow of water to move blocks of this size down slopes of the order of 2 or 3° and leave them dumped in such a regular fashion.

It may be argued that these are lag deposits connected with spring sapping at the foot of each terrace, perhaps more vigorous in the past. But then some of this spring sapping should be occurring at the base of bedrock (or more or less bedrock), and not consistently with boulder cascades except for the highest terrace in any sequence. The restriction of these terraces to the heads of the highest valleys in E. Victoria and their absence from morphologically similar valley heads in identical rocks at slightly lower altitudes shows this could not be the fundamental cause. A simple interpretation as glacial moraine would ignore the occurrence of these terraces with boulder ramparts at the head of small valleys, in such a position that there could not have been sufficient head of snow to make a hypothetical glacier move there. The absence of intermediate grades of rock debris from the accumulations is likewise against interpretation as moraine.

The regularity of the terraces and their lack of relationship to cliffs show they cannot be due simply to rock fall followed by accumulation behind the barrier. On the other hand, their intimate relationship with running water at the present day indicates there was almost certainly some connection with water in their genesis. Solifluction and frost heaving were considered an adequate cause of similar block cascades in Wisconsin by H. T. U. Smith (1949). Certainly the freezing of water in the interstices giving an outward thrust would explain the movement of the large boulders a ton or more in weight. The significance of solifluction cannot be estimated for there is no certainty these terraces contained an appreciable amount of soil at the time they were generated; excavation did not clarify this point. Solifluction or no, the size of the blocks in these boulder cascades is so similar to that of the rock rivers in the same area that I am led to conclude they are different facets of an essentially similar process, the one occurring on steep slopes with freezing of waters from a subjacent spring in the interstices of the accumulation, the other occurring on gentler slopes with serial generation of terraces corresponding to a series of springs, with the same process of filling of interstices with ice giving an outward thrust in each case. In the case of the Cobberas No. 1 amphitheatre it seems clear that the generation of many of the boulder cascade terraces has taken place with materials supplied by rock rivers. Elsewhere the two phenomena tend to be separate, but wherever rock rivers emerge onto comparatively gentle slopes, as for example along the NW. flank of Mt Wombargo, they are frequently stepped. A more detailed study of these terraces should take into account possible relationships to the Russian 'goletz' and the altiplanation terraces of North America.

Mr Eric Woodford has drawn my attention to single terraces with boulder ramparts developed on the E. side of small rhyodacite peaks near the heads of Goodwin and the Lower Limestone Ck NW. of Wulgulmerang. Each of them is associated with bogginess or weak spring activity, and in each case there is a noticeable amphitheatre effect, but all of them have the appearance of long inactivity. They are clearly single terrace examples of the same phenomena just described and more elaborately developed on the peaks about The Cobberas and Mt Wombargo.

The Cobberas Amphitheatres

Cirque-like valley heads are widely distributed in the Victorian highlands associated with a variety of lithologic and structural controls. They may be found in association with slumping of clayey sediments, with solution effects on carbonate rocks, and around the margins of Tertiary basalts where there has been spring sapping. Some of the valley heads developed on rhyodacites about The Cobberas (Fig. 3) have pronounced amphitheatre shapes and on such a scale that they warrant more than cursory mention. One of them has already been described as a glacial cirque (Costin 1957), and indeed others could be described as cirques were it not for the absence of moraine, the absence or near absence of clay in such accumulations as occur within them (see above under rock rivers and boulder cascades) and, in the case of weaker forms, the occurrence of similar forms at lower altitudes on rhyodacites elsewhere in the Snowy River Volcanics belt. The largest of these amphitheatres formed by Cobberas No. 1 about the head of Towanga Ck is not illustrated because the flights of timber-assessing photos used in Pl. 22 did not give stereo cover for that area. The coverage for Cobberas 1 mile sheet at a scale of approx. 1: 31,300 (cf. Pl. 21), while adequate for field work, was not good enough over Cobberas No. 1 for reproduction; some description is therefore necessary. Contours of this area are to be found on the standard topographic sheet Cobberas (Victorian Lands Department) and the 1 mile to 1 inch geological plan of Cobberas 1 mile sheet (Talent et al. 1964).

Cobberas No. 1 is sickle-shaped in plan, opening ESE. and exceeding 6000 ft at the Cleft Peak in the N. and at the Trig Peak located at the junction of 'handle and blade'. It is of pronounced amphitheatre shape, 1½ miles across at its widest, with slopes of the order of 20°, steepening to an average of 27° down rock rivers, to 50° on rocky outcrops and with a few cliffs, mainly around the crest, of 70° to nearly 90°. The floor flattens to a minimum gradient of only a few degrees along Towanga Ck and the boulder cascades in the centre of the valley, then descends 850 ft in a horizontal distance of half a mile, the first 400 ft being by a series of waterfalls. It requires special consideration because it has been described (Costin 1957) as having the 'form of a large shallow cirque at the base of which are large accumulations of boulders, in the form of moraine, now largely vegetated' in addition to 'smaller accumulations of smaller stones . . . largely unvegetated' farther upslope, and 'tiny cirque-like hollows on the eastern side'.

Except for recent talus, the various boulder accumulations of the Cobberas No. 1 amphitheatre are described above. Though I regard the boulder cascades and the rock rivers to be Pleistocene in age, I could not conceive that any of these accumulations were moraine, nor could I find evidence of two periods of development characterized by size of boulders and degree of vegetation. One barer deposit in the middle of the amphitheatre (Pl. 19, fig. 5), perhaps one of the 'smaller accumulations of smaller stones' referred to by A. B. Costin, has been described above and its relative bareness ascribed to causes other than lack of antiquity. The boulder cascades do run across the valley as one might expect of moraines, but the rock rivers themselves are aligned down the sides of the amphitheatre from the bluffs, analogous to the paths taken by streams of water. There is no difficulty discriminating between these older deposits and recent talus or rock fall, though the volume of talus is small considering the peaks about The Cobberas are some of the most rugged in E. Victoria (cf. Pl. 18, fig. 1-4; Pl. 23).

The main problem for consideration is why the Cobberas No. 1 amphitheatre (abnormally large for a cirque), the amphitheatres on either side of it, and the one on the side of Cobberas No. 2 are hanging with respect to Towanga, Native Dog, and Moscow Ck and why they have a similar morphology. Close analogues of these amphitheatres do not occur on adjacent peaks such as Blue Hill, Big Hill, or Mt Wombargo and are not found on other high peaks in the region: Mt Pinnibar, Mt Gibbo, Mt Nuniyong. This suggests peculiar local circumstances, particularly as the most cirque-like of these amphitheatres (Pl. 22), draining into Native Dog Ck, is lower than the others (not quite 5000 ft above sea level) and is not backed by a considerable catchment for snow.

A bending profile down the Cobberas No. 1 amphitheatre could be projected to join the head of Native Dog Ck without a notable change in gradient. It may be, therefore, a dismembered portion of that creek captured by the rejuvenated Towanga Ck. This would account for the knick point and waterfalls, but would not account for the amphitheatre joining Towanga Ck farther to the NE., nor the amphitheatre on Native Dog Ck 1⅜ miles SW. of Cobberas No. 1 Trig Peak having a rather similar morphology. It seems to me significant that both Towanga and Native Dog Ck are located on the same NE.-SW. lineament and that creeks to the N. can be grouped in pairs on parallel lineaments: Bullies Ck and the right branch of Moscow Ck; Surveyor Ck and the left branch of Moscow Ck. Streams to the S.—James and Rocky Plains Ck and the heads of Fish Ck have all picked up the same direction. I believe these to be old fault zones, but this has not been verified. However that may be, they are lines of easier excavation which have been picked out by the main drainage so that streams running across the adjacent rhyodacites have difficulty competing with the speed of downcutting of the main drainage; they are accordingly left in a hanging position.

If this explains the hanging relationship of the Cobberas amphitheatres to the main drainage, it still does not explain their shape. Could they be glacial? The possibility of some glacial action cannot be denied, but there is no strong supporting evidence other than the shape (gentle compared with the overdeepened cirques at Mt Kosciusko) and an orientation roughly towards the SE. On the other hand, I have found no indubitable polish, striae, plucking, or moraines associated with these amphitheatres. What happened to the immense volume of rock carved out in producing these forms? Why has it been completely removed from the amphitheatres and the valleys farther downstream? It seems to me these amphitheatres are much older than the period of refrigeration responsible for the periglacial deposits now draping their sides and floors. Because of the absence of proved moraine or other indubitable evidence of glaciation I hesitate to refer the amphitheatres to an earlier period of refrigeration. Rather I regard them as due to differential erosion of very hard rocks over a long period of time in which zones of shattering, closer jointing, and subtle differences in lithology have been picked out.

Solifluction Deposits

The apparent rarity of thick solifluction deposits in the Victorian highlands may be due to lack of investigation for there are two notable deposits exposed in road cuttings on the Alpine Highway at Mt Hotham which have not been recorded.

One deposit is located at the Diamentina Drift in a NE.-facing valley head of the Diamentina R. around the 6000 ft level about 25 chains W. along the Alpine Way from the junction with the road to the Red Robin Mine. It is a jumble of soil and rock fragments formerly exceeding 20 ft in maximum thickness and being about 70 yds across at its widest point. Part of it above the Alpine Highway has been excavated for road construction material; the surface has since been smoothed out. Part of it lies below the road and was formerly overlain by a moss bog; this has been destroyed and erosion has cut into the distal end of the accumulation. It is the site of a fairly persistent snow drift.

A similar deposit occurs at the Davenport Drift on the Alpine Way about 1 mile SE. of the junction with the road to the Red Robin Mine. It is a similar deposit to that at the Diamentina Drift, facing ENE., except that it is on a steeper slope and has been developed from basaltic soils and basalt boulders. The boulders have been broken down to lumps 1-4 in. across with occasional larger lumps, mixed with a lot of soil to an unknown depth (several feet). The size of the basalt boulders provides a contrast with the larger basalt boulders littering the surrounding slopes. Frost action is indicated by the angularity of the fragments and degrees of comminution of the boulders.

Cutting of the Alpine Way has caused some renewed downslope movement of both deposits, though removal of much of the Diamentina Drift deposit has arrested this activity. In both cases there is annual deep freezing of these water-saturated accumulations (K. Terry pers. com.). Both deposits are essentially fossil, but in view of this it is uncertain to what extent they are Pleistocene.

Stepping of Upland Valleys and Slopes

The stepping of valleys and slopes may reflect a dominant structural control such as bedding or major jointing; it is most conspicuous when associated with sharp contrasts in lithology. Further comment is necessary because stepping, in association with other geomorphic forms, has been adduced as evidence for Pleistocene glaciation of the Baw Baw and Buffalo granitic massifs, the basaltic Dargo High Plains, and the Snowy Plains-Mt Wellington area (Costin 1957).

1. Stepping on the Baw Baw and Buffalo Granitic Massifs

It is well known that the rectangular drainage pattern and the stepping of valleys on granitic rocks is controlled by major joint patterns and by faults and dykes of igneous rocks and are developed under a variety of climatic conditions. The following discussion, therefore, will not probe this fundamental principle, but will consider only the two areas of Victoria where valley stepping on granitic rocks has been attributed to glacial or periglacial activity.

The geology and scenery of the Buffalo Plateau has been mapped, described, and copiously illustrated by E. J. Dunn (1908). It is sufficient, therefore, for the present discussion to reiterate that the landscape there is dominated by a rectangular drainage pattern among rocky residual peaks (tors). Rock buns, known in Victoria as tors, are widespread; there is a general absence of rocky material from the narrow, treeless, poorly drained, peaty flats along the principal watercourses except in the vicinity of stepping or near the margins of the plateau. A. B. Costin (1957, p. 234), in discussing this area, refers briefly to the valley of the creek leading to Dickson's Falls being of this general type except that 'a short distance upstream from where the tourist road to the Horn crosses the creek . . . the valley narrows suddenly and the creek cascades down through about 100 yards of boulders'. This, along with the 'bouldery condition of the rest of the plateau' (presumably the rock bun dominated landscape) and the 'virtual absence of large boulders from the broad expanse of valley' was regarded as consistent with the existence of a cirque glacier or even a small valley glacier.

An explanation of the relative absence of boulders and rock buns from the peaty valley floors must take into account the acid conditions prevailing in these tracts, the augmented weathering of felspar in granitic rocks in this environment, the accumulation of soils on these flatter areas, and inorganic and organic sedimentation in a swampy milieu. The rock buns are demonstrably generated in situ from large joint blocks by weathering along joints coupled with exfoliation of surfaces exposed to the atmosphere (discussed in Dunn's memoir). Where there are road cuttings exposing rock and rotten granite, the joint pattern of the granite will be found to continue uninterrupted into the weathered rock with patches of less weathered or more or less unweathered granite blocks retaining their structural relationships to one another (Pl. 17, fig. 4) and in harmony with the jointing of the granitic bedrock. Such assemblages have not been moved, though with deflation of the surface by wind, water, and hillside creep they would become part of the loose rock on the surface. No cuttings reveal unusual accumulations of granite boulders or boulders requiring movement by ice to explain their occurrence.

At the top of the previously mentioned cascade there are 27 yds of unbroken outcrop of granite bedrock (Pl. 17, fig. 3); massive granite outcrops in the bed of the cascade for 7 out of every 10 yds of its descent. The intervening cover is thin, with other granite outcrops, some of which could well be continuous with the bedrock. There is only one set of blocks rising above the general surface—it is located right at the top of the cascade. It retains the joint directions of the granitic bedrock showing it has developed in situ (Pl. 17, fig. 5); it has been neither dumped nor moved. The stepping of the valley (Pl. 17, fig. 6) at this locality accordingly is not connected with glacial moraine. It is related to the major jointing of the granite, though I have not gone into the details of its generation.

Similar considerations are involved in the geomorphology of the Baw Baw Plateau. There are the same broadly concave valleys, peaty flats, tors, rock buns, and strong control of drainage by the rectangular pattern of major joints in the granite (Baragwanath 1925, p. 25, 19, Pl. 15-18, map). The stepping of Tullicoutty Glen (cf. Pl. 20, fig. 2) and the heads of the Tanjil R. (Pl. 20, fig. 1) and Whitelaw Ck (Costin 1957) is considered to be explicable by the normal processes of erosion without need to invoke glaciation or periglaciation. The major stepping at the head of Tullicoutty Glen noted by A. B. Costin coincides with a major NE.-SW. joint or shear which can be traced for approximately 6 miles across the Baw Baw Plateau. The change downstream from a broadly concave to a V-shaped valley coincides with a convergence of two major NW.-SE. joints controlling as well the direction of the two heads to the glen. A search of this valley did not prove the existence of moraine. The head of the West Tanjil R. and its tributaries shows a remarkable set of steps and rectangular control of drainage by the pattern of major joints (Pl. 20, fig. 1), with constriction of valleys at each major step. If this were essentially due to glaciation it would be anomalous for the glaciers would have to have taken right angle bends.

2. STEPPING ON BASALTIC HIGH PLAINS

The normal law of retreat of lava-capped summits is as a series of steps separated by noticeably steeper slopes due to the layered nature of lava accumulations and to interbedded sediments, soil horizons or volcanic ash. Such stepping has not previously been emphasized in Victoria, but its occurrence on Tertiary basalts at all altitudes down to sea level shows this is not necessarily due to glacial or periglacial activity.

Stepping has already been recorded for the basalts of the Bogong High Plains (Carr and Costin 1955). These remnants are known to consist of many flows with interbedded tuffs and sediments (Beavis 1962). Mapping of the Nuniyong-Nunnet Plains area and boring of the Dargo High Plains has shown these bodies of basalt to be complex and that there is a connection between terracing and layering.

There have been several accounts of the geology of the Dargo High Plains with reference to the mining of the deep leads beneath the basalt, culminating in a detailed geological map on a scale of 40 chains to the inch (Hunter 1895). In 1900 and 1901, an E.-W. line of 5 bores was drilled there at Gow's Plains by the Mines Department of Victoria; 4 of these reached bedrock and the fifth terminated before reaching the deep lead beneath the basalt sequence. The published logs of 4 of these bores (Hunter 1902) indicate up to 8 discrete flows, some separated by beds of lignite, clay, and sand, and others separated by zones of vesicular basalt or decomposed basalt. It is possible to recognize some of these differing flows in the hand specimen on the basis of their texture and weathering characters and to demonstrate that some at least of the steps about Gow's Plains correspond to changes in lithology of the basalts. Correlation between stepping and layering of the basalts seems reasonably proved; this is reinforced by the restriction of stepping to the basaltic area and its absence from the adjacent Ordovician sediments at higher and lower levels than the basalts.

There is remarkable stepping of the previously unmapped large area of Lower Tertiary basalts extending from Emu Plains through the Nuniyong and Low Plains to Nunnet Plains (Fig. 2 for localities; Fig. 4 for profiles). There is a difference in height of more than 700 ft between the highest surface of this basalt body on Lake Hill, seemingly a slightly modified relic of the Lower Tertiary surface after extrusion of the basalts, and the lowest level of basalt in the Timbarra Gorge 3 miles to the SW.; an appreciable relief of the Lower Tertiary surface is indicated for this area. There is major stepping of the area with Lake Hill standing as a mesa above the surrounding plains with a series of gross terraces in most directions as one descends from it, with smaller terraces between and within the various plains to the limits of the basalt (Pl. 17, fig. 1, 2); there is often a well defined terrace between the basalt and the exhumed granite surface surrounding it. Some of the terracing is demonstrably connected with variation between basalt flows observable in the hand specimen (vesicularity, crystallinity, macroscopic olivine content and weathering characters).

Though terracing of the basaltic high plains can be shown in part at least to be due to layering of the basalts and interbedding of sediments and tuffs, the steepening of slope at each terrace would have provided a favourable situation for frost prising and, in steeper situations, the generation of block streams under periglacial conditions. As was discussed earlier and has been recognized by other workers (Carr & Costin 1955, Costin 1957) this is what occurred around the basaltic high plains of Victoria during the Pleistocene.

Concluding Remarks

Above about 5000 ft in the Victorian highlands the familiar processes of erosion at lower altitudes are supplemented by an increase in frost heave and frost spalling indicating an approach to an alpine regimen. Our knowledge of these processes in Victoria is rudimentary and needs to be expanded as a preliminary to disentangling what is contemporary and what should be attributed to a past alpine or periglacial regimen. It is not surprising that fossil periglacial features are not particularly conspicuous or may even be absent over considerable areas where they formerly existed, for substantial changes in micro-geomorphology will have resulted from overall erosion and other geomorphological processes since the Pleistocene. Unprotected and weakly expressed glacial or periglacial forms would have been readily erased. Some grosser products of periglaciation such as large rock rivers, stepping of valleys with boulder cascades and solifluction deposits have survived as fossil features testifying to past refrigeration. The significance of lithology and structure should be evaluated before a glacial, periglacial, or other origin is ascribed to a given geomorphic form. Ignoring these factors, or, conversely, overemphasizing them, may lead to distorted or erroneous views of their genesis.

Acknowledgements

The writing of this paper has benefited greatly from discussion with Dr Marjorie Sweeting, Oxford University; Dr O. P. Singleton, Melbourne University; Mr Ken Terry, Soil Conservation Authority; and many of my colleagues at the Geological Survey of Victoria. My wife Joan and Miss Marjorie Hall helped substantially in integrating the paper. The air photos on Pl. 20-23 have been reproduced with the permission of the Lands Department of Victoria. The Mines Department of Victoria generously covered the cost of production of the plates.

Cited Literature

Baragwanath, W., 1925. The Aberfeldy district (Gippsland). *Geol. Surv. Vict. Mem.* 15: 45 p., 19 pl.

Beavis, F. C., 1959. Pleistocene glaciation on the Bogong High Plains. *Aust. Jour. Sci.* 21: 192.

———, 1962. The geology of the Kiewa area. *Proc. Roy. Soc. Vict.* 75: 349-410, Pl. 39-42.

Browne, W. R., 1957. Pleistocene glaciation in the Commonwealth of Australia. *J. Glaciology* 3: 111-115.

Browne, W. R., and Vallance, T. G., 1963. Further notes on glaciation in the Kosciusko region. *Proc. Linn. Soc. N.S.W.* 88: 112-129.

Capps, S. R., 1910. Rock glaciers in Alaska. *Jour. Geol.* 18: 359-375.

CARR, S. G. M., and COSTIN, A. B., 1955. Pleistocene glaciation in the Victorian Alps. *Proc. Linn. Soc. N.S.W.* 80: 217-228, Pl. 7, 8.

COSTIN, A. B., 1957. Further evidence of Pleistocene glaciation in the Victorian Alps. Ibid. 82: 233-238, Pl. 10.

DUNN, E. J., 1908. The Buffalo Mountains. *Geol. Surv. Vict. Mem.* 6: 11 p., 53 pl.

GALLOWAY, R. W., 1963. Glaciation in the Snowy Mountains: a re-appraisal. *Proc. Linn. Soc. N.S.W.* 88: 180-198, Pl. 12.

HOWITT, A. W., 1891. Notes on Lake Karng. *Rep. Stat. Mining Dept [Vict.], quarter ended 30th Sept. 1891:* 26-30, Pl. 1-4.

HOWITT, A. W., LUCAS, A. H. S., and DENDY, A., 1891. A visit to Lake Nigothoruk and Mount Wellington district. *Vict. Naturalist* 8 (2-3): 17-40.

HUNTER, S. B., 1895. Geological plan of Dargo High Plains. *Dept Mines, Vict.*

————, 1902. Records of boring operations—Dargo High Plains. *Ann. Rep. Sec. Mines & Water Supply [Vict.] for 1901:* 113, map.

JENNINGS, J. N., 1956. A note on periglacial morphology in Australia. *Biuletyn Periglacjalny* 4: 163-168.

MCELROY, C. T., 1952. Contour trench formations in upland plains of New South Wales. *Jour. Proc. Roy. Soc. N.S.W.* 85: 53-62, Pl. 5.

NEILSON, J. L., 1962. Notes on the geology of the high plains of Victoria. *Proc. Roy Soc. Vict.* 75: 277-284.

ROYAL SOCIETY OF VICTORIA, 1962. The Victorian high plains symposium. Ibid. 75: 275-410.

SMITH, H. T. U., 1949. Periglacial features in the driftless area of southern Wisconsin. *Jour. Geol.* 57: 196-215, 4 pl.

TALENT, J. A., BOCK, P. E., and GLENIE, R. C., 1964. Geological map Cobberas one mile sheet. *Dept. Mines, Vict.*

THIELE, E. O., 1905. A trip to Lake Karng and Mt Wellington. *Vict. Naturalist* 22 (2): 22-30.

TYRRELL, J. B., 1910. 'Rock glaciers' or chrystocrenes. *Jour. Geol.* 18: 549-553.

Explanation of Plates

PLATE 17

Fig. 1, 2—Stepping of Tertiary basalts, SE. side of Nuniyong Plains (cf. Fig. 4 in text). Such stepping is typical of the Nuniyong-Nunnet Plains and Dargo High Plains basalt residuals.

Fig. 3—Massive outcrop of granite bedrock at the head of the step on Dickson's Falls Ck, Buffalo Plateau, attributed by A. B. Costin (1957) to glacial activity.

Fig. 4—Typical example of persistence of jointing of granite into the weathered zone on abandoned portion of the road to The Horn, Dickson's Falls Ck, Buffalo Plateau. Such examples, being typical, argue against anomalous movement and accumulation of granite boulders on the plateau.

Fig. 5—Outcrop of granite near the top of the step on Dickson's Falls Ck, Buffalo Plateau. Note the retention of primary joint directions indicating development in situ and eliminating the possibility of glacial transport..

Fig. 6—The broad, stepped valley of Dickson's Falls Ck, Buffalo Plateau from the road to The Horn attributed by A. B. Costin to the activity of a cirque glacier or small valley glacier. Note the rock buns and the absence of rocky material from the valley floor.

PLATE 18

Fig. 1, 2—Strong columnar jointing of rhyodacites (incandescent tuff flows) on a bluff on the side of the amphitheatre of Cobberas No. 1, NNE. of the Trig Point. It is such pronounced jointing, comparable with that more normally associated with basalts, which provided excellent locales for the generation of large volumes of blocks for the Pleistocene rock rivers descending the slopes of the amphitheatre. There is surprisingly little recent rock fall or talus from such bluffs.

Fig. 3—Similar strong columnar jointing of rhyodacites on the Middle Peak of Cobberas No. 1 at the top of a large overgrown rock river descending into the Cobberas No. 1 amphitheatre.

Fig. 4—Middle Peak, Cobberas No. 1, typical of numerous rhyodacite peaks scattered through the Cobberas-Wombargo mountains, though more strongly jointed than most. Note the steeper profile on the E. facing (right side) of the peak; it is this side which generated a rock river during the Pleistocene.

Fig. 5—Contemporary frost spalling of rhyodacite, Trig Peak, Cobberas No. 1.

Fig. 6—'Pencil shales' being prised out with the aid of frost, Diamentina Drift, Mt Hotham.

1

2

3

4

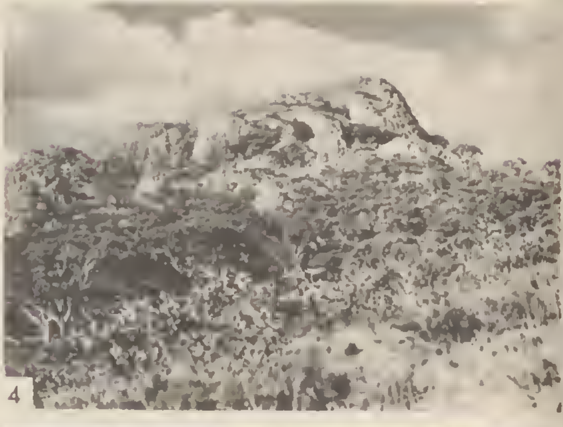
5

7


1


2


3


4


5


6


1

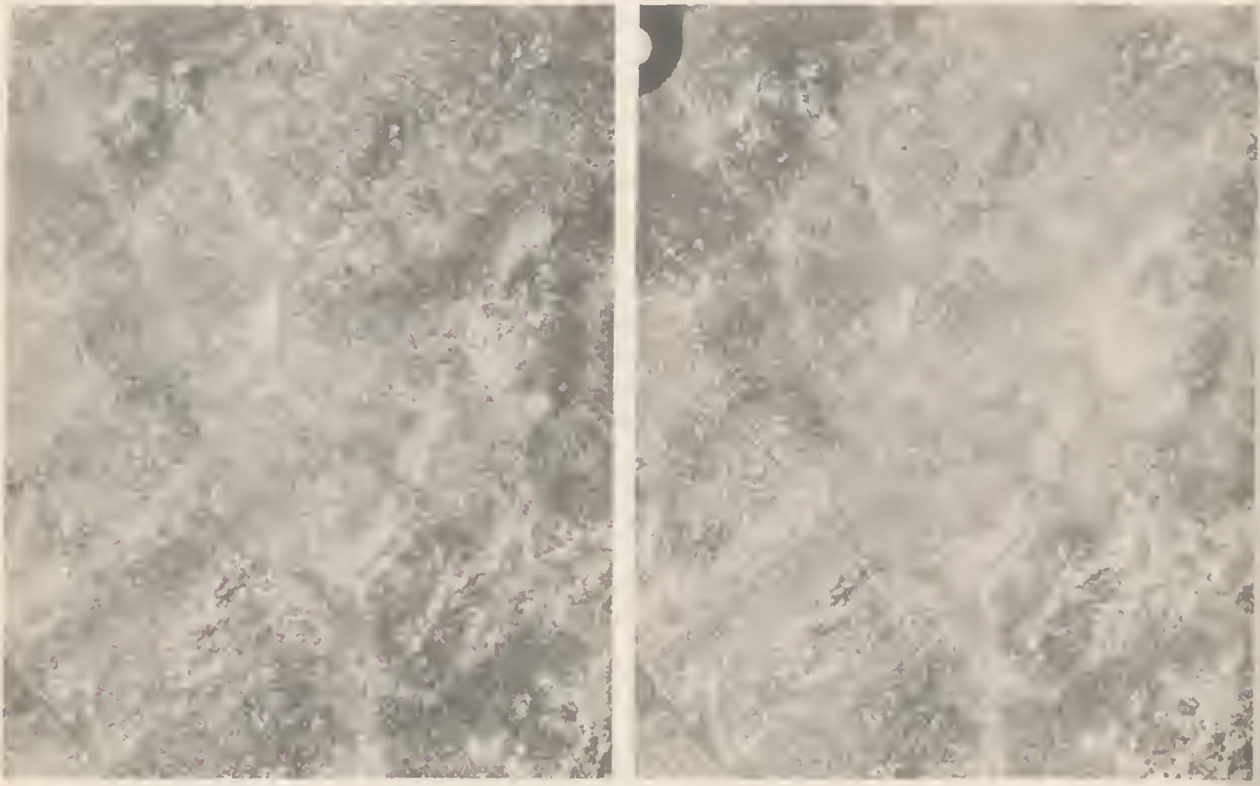

2


3

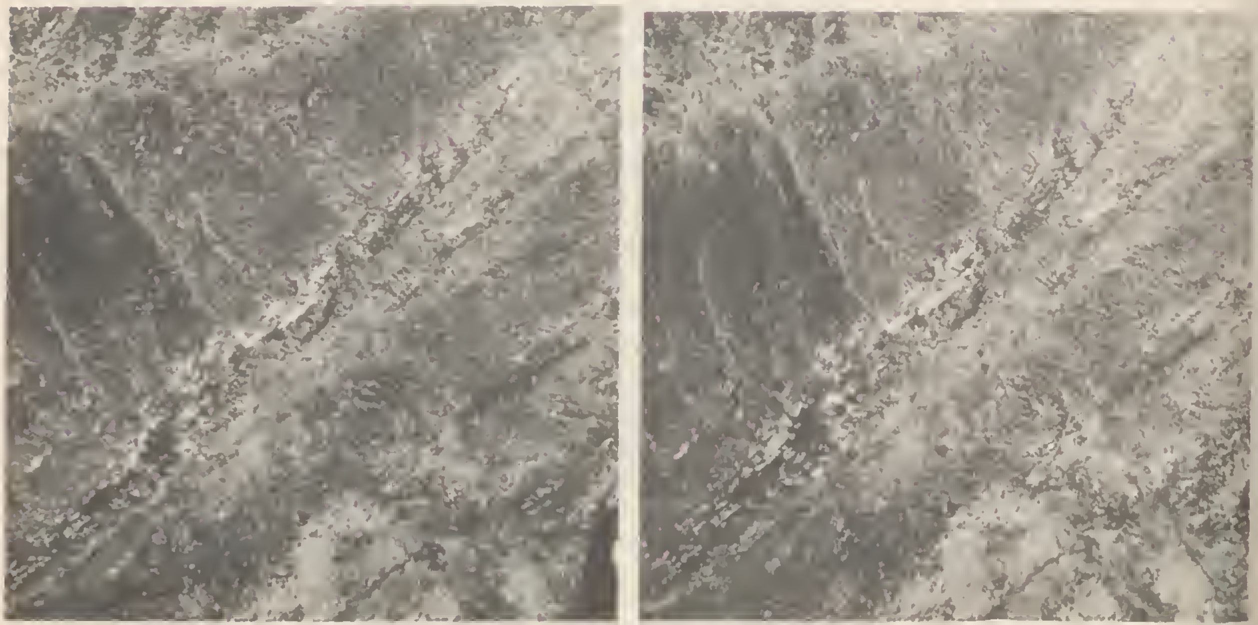

4


5

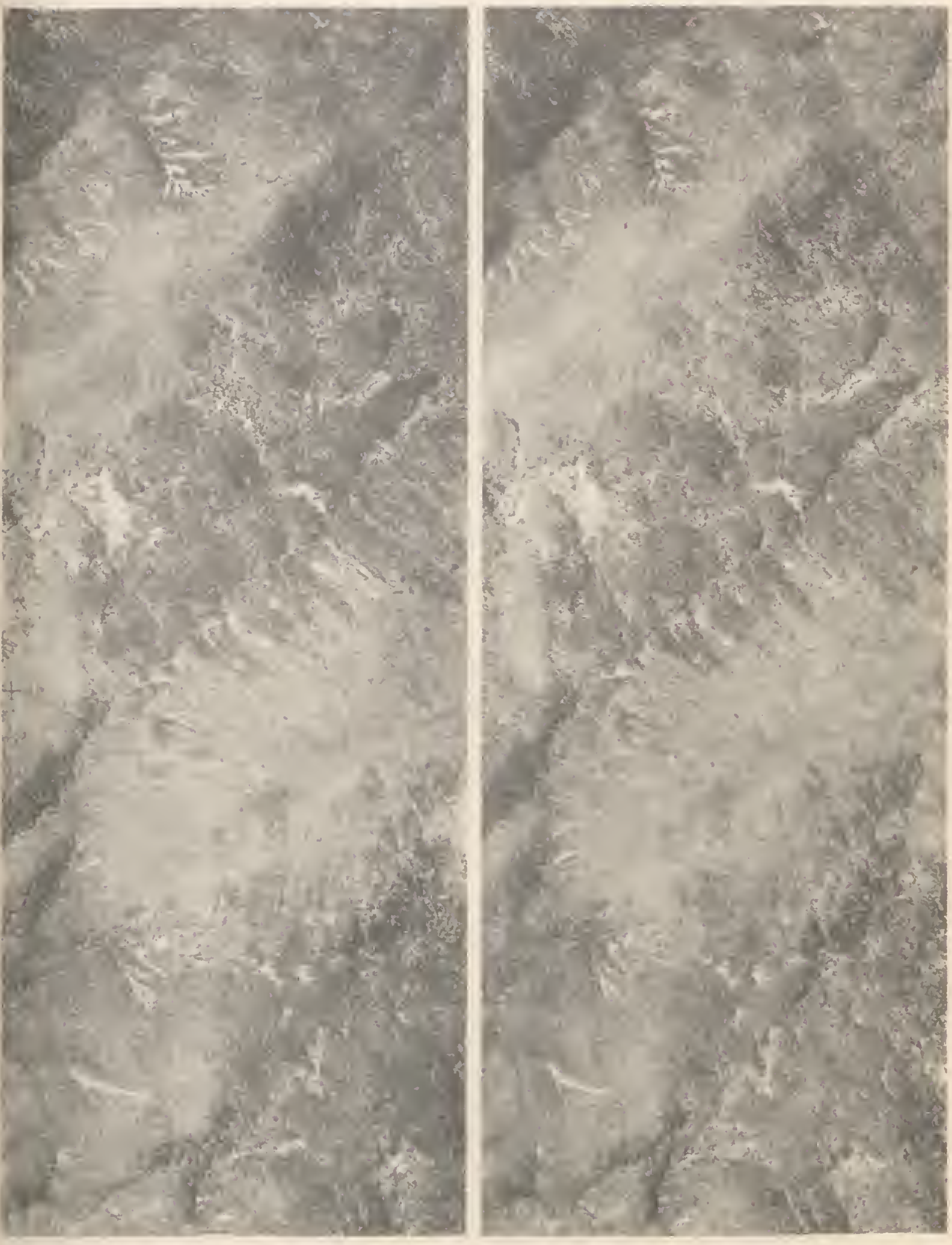

6

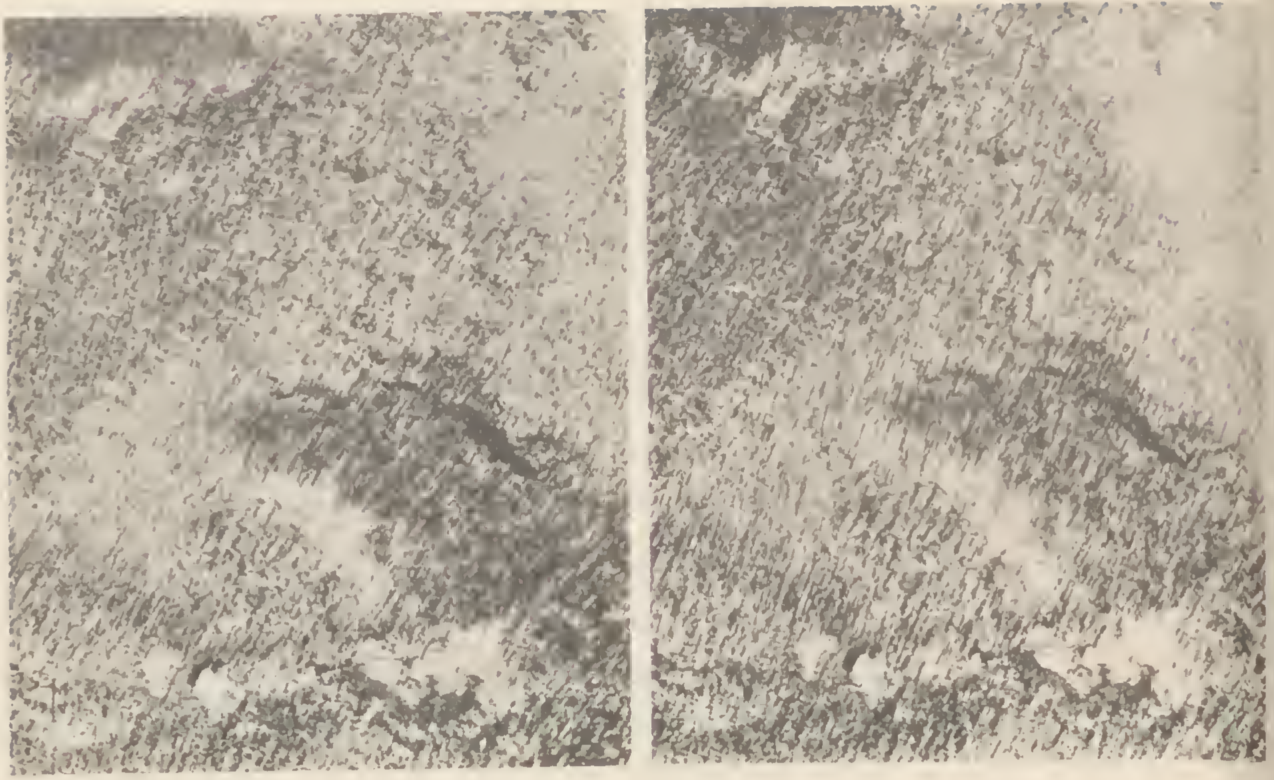


1

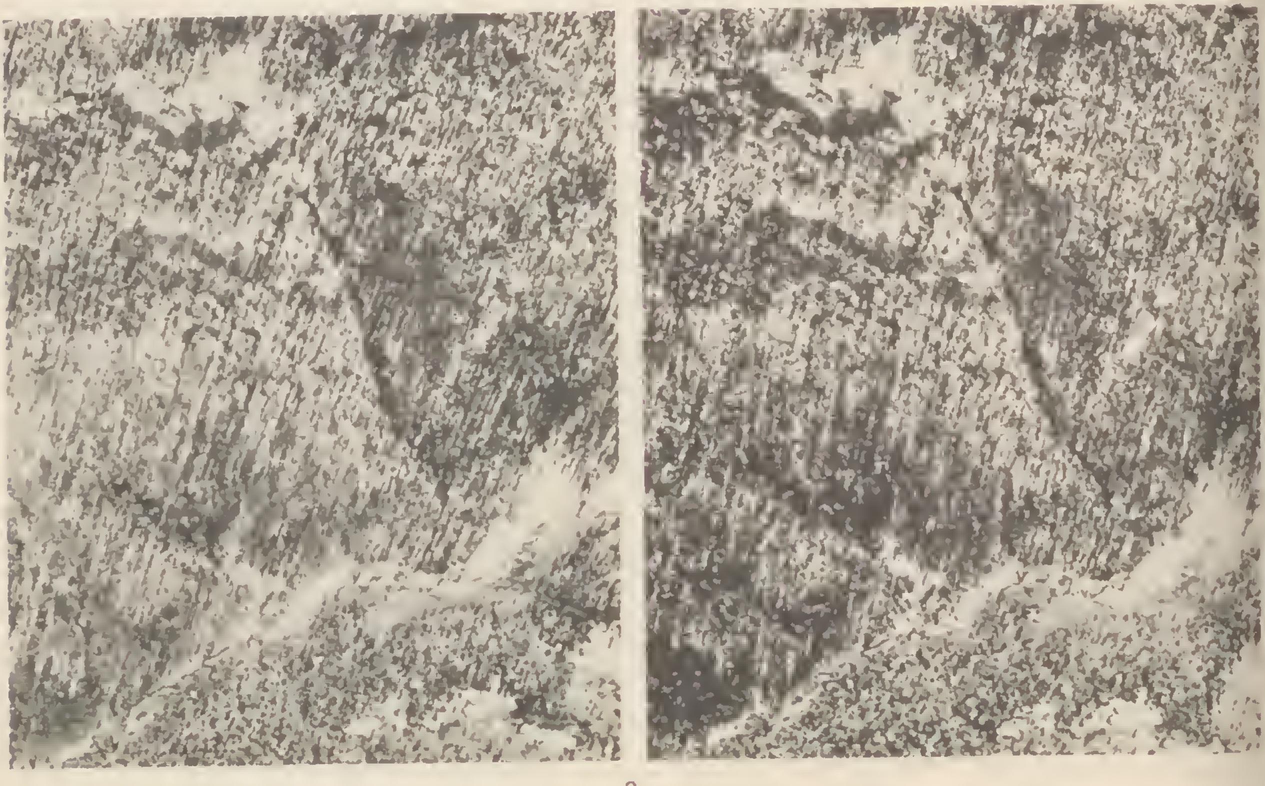


2

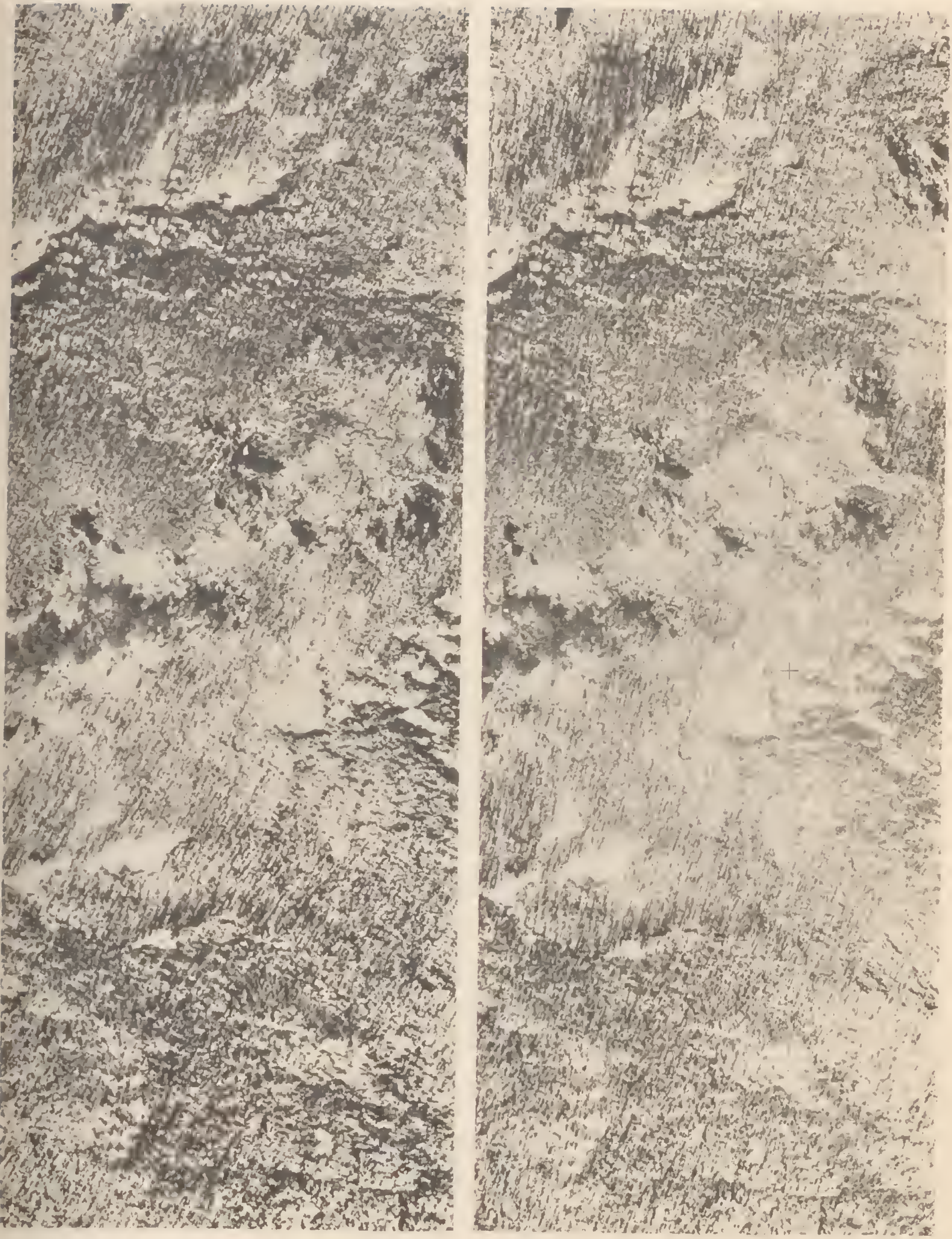




1



2



Such frost prising of fissile sediments becomes marked above about 5,000 ft. There is an increase in angular spalls of metamorphics (other than granitic gneisses) and arenaceous sediments above the same general level, even where there is a reasonably continuous cover of vegetation apparently in a state of equilibrium, thus testifying to the increased potency of frost above this level.

PLATE 19

Fig. 1-3—Various views of the rock river on the NW. side of Mt Wombargo surveyed for Fig. 4 of the text. Fig. 1—looking up 26° slope close to the Native Dog Plain-Black Mt jeep track. Fig. 2—flatter, broader track immediately above the surveyed portion; the rock river extends laterally into the timbered area to its sides; note the lichen mottling of the boulders. Fig. 3—abnormally large boulder in rock river; much larger boulders may be found.

Fig. 4—Rock river exposed by Towanga Ck a short distance upstream from the Towanga Ck Falls, Cobberas No. 1 amphitheatre; the rock river has descended the slope from the Cleft Peak. Note the antiquity of the boulders indicated by their fretted surfaces; such fretting of boulders is typical for all the rock rivers of the Cobberas-Wombargo mountains.

Fig. 5—Small crescent-shaped boulder terrace in Cobberas No. 1 amphitheatre, anomalous in lacking vegetation on the terrace surface and in lacking lichen mottling of the boulders; antiquity is indicated by the fretted surface of the surface boulders, contrasting with smooth boulders beneath the surface.

Fig. 6—A flatter terrace-like part of the surveyed rock river on the NW. side of Mt Wombargo; the flattening is exaggerated by looking down the slope.

PLATE 20

Fig. 1—Stereo pair of the headwaters of the West Tanjil R. showing the strong control of drainage pattern and the stepping associated with the major joint system of the Baw Baw Granodiorite. The lower margin is oriented approximately N.-S., with N. to the right; it is located approximately 400 yds W. of Mt Phillack. The left (E.-W.) vertical margin is located approximately 400 yds N. of Mt Baw Baw.

Fig. 2—Stereo pair of Tullicoutty Glen showing strong control of drainage by major joints. Note the two heads of the glen following major NW.-SE. joint directions and joining with a major step in profile coincident with a major NE.-SW. joint or shear direction. Note the convergence downstream of these two shears or major joints controlling the direction of the glen and the associated narrowing of the glen downstream. The right margin is approx. 400 yds S. of Mt Phillack. Scale approximately 20 chains to 1 inch.

PLATE 21

Stereo pair of Mt Wombargo (lower centre)and Big Hill (upper) on the watershed between the Buchan and Suggan Buggan R. Almost 60 rock rivers appear on these photos as pale stripes or vague lines attenuated downslope. There is a notable preference for N. and W. facing slopes. The vertical direction is N. Scale approximately 50 chains to 1 inch.

PLATE 22

Fig. 1—Stereo pair of a small creek draining into Native Dog Ck (or Upper Buchan R.) about 1¾ miles WSW. of the Trig Peak of Cobberas No. 1 showing the markedly cirque-like shape of the valley head (exaggerated) and terraces with boulder cascades in the branch from the left (W); the terraces are emphasized by snow. Similar terraces occur in the tributary from the N. but are less clearly shown. The saddle above the amphitheatre stands at a level of just over 5000 ft and the ridge on the upper right corner is between 5250 and 5300 ft high. The vertical direction is N. Scale approximately 20 chains to 1 inch.

Fig. 2—Stereo pair of the same creek as fig. 1 above from another air photo flight to show the same terraces and the hanging position of the amphitheatre, in which they occur, relative to Native Dog Ck. Same details as fig. 1.

PLATE 23

Stereo pair of the head of Bullies Ck, Surveyor's Ck (upper left) and Moscow Ck (right); the ridge on the lower right leads to Cobberas No. 1 between the Middle and Cleft peaks. Note the strong terracing of the head of Moscow Ck due to boulder cascades, and less well defined terracing of the head of Surveyor's Ck, terracing emphasized by snow lying on the terraced areas. An Abney level traverse through the terraces on Moscow Ck is shown in Fig. 4 of the text. Vertical is N. Scale approximately 20 chains to 1 inch.

Brown, Prior, Anderson Pty. Ltd., 430 Little Bourke Street, Melbourne, C.1

8

MICROPLANKTON FROM THE PALEOCENE PEBBLE POINT FORMATION, SOUTH-WESTERN VICTORIA

PART 1

By ISABEL C. COOKSON
Botany Department, University of Melbourne

Abstract

Three new species, namely *Svalbardella australina*, *Trichodinium hirsutum*, and *Cyclonephelium vitilare* are described from the Pebble Point Formation in Victoria. Previous records of *Cannosphaeropsis caulleryi* Deflandre from this Formation are reconsidered.

Introduction

Several microplankton species have already been recorded (Deflandre & Cookson 1955) from the Paleocene deposits comprising the Pebble Point Formation, but hitherto no attempt has been made to determine the composition of the assemblages present at specified levels.

Recently the commencement of such a project was made possible by the provision of samples taken at 4, 6, and 30 ft from the base of the Pebble Point Formation on the SE. side of Dilwyn Bay, SW. Victoria, by Messrs W. K. Harris and D. J. Taylor of the South Australian and Victorian Departments of Mines respectively.

This contribution deals with 3 new species of Dinophycaeae from the 4 ft and 6 ft levels. Of these, 2 have been recovered from the deposit sampled at 4 ft from the base of the Formation, the third species from both the 4 and 6 ft samples. The occurrence of *Cyclonephelium retiintextum* Cookson at 4 and 6 ft is recorded.

The figured specimens have been placed in the National Museum of Victoria under the numbers P 23118-23127, and P 23448-23457.

Systematic Descriptions

Class DINOPHYCEAE

Family AREOLIGERACEAE Evitt

Genus **Cyclonephelium** Deflandre & Cookson 1955
emended Cookson & Eisenack 1962

Cyclonephelium retiintextum Cookson

(Pl. 24, fig. 8-11)

Cannosphaeropsis cf. *caulleryi* Deflandre. Cookson 1953, p. 117, Pl. 2, fig. 35-40.
Cannosphaeropsis caulleryi Deflandre. Deflandre & Cookson 1955, p. 283, Pl. 7, fig. 8.
Cannosphaeropsis caulleryi Deflandre. Cookson & Eisenack 1961, p. 44, Pl. 2, fig. 12.
Cyclonephelium retiintextum Cookson 1965, p. 88, Pl. 11, fig. 4.

AGE AND OCCURRENCE: Paleocene: Pebble Point Formation, SW. Victoria, at 4 ft and 6 ft above the base.

COMMENT: Specimens herein referred to the Australian Upper Cretaceous species *Cyclonephelium retiintextum* are, by their large number and striking appearance, the most conspicuous feature of the microplankton assemblages of the samples taken at 4 and 6 ft, particularly the one at 4 ft, from the base of the Pebble Point Formation. As can be expected in such a rich population, there is considerable variation in the number and length of the processes composing the network which is situated within the margin of both surfaces of the shell. However, in spite of this variation, both the mode of construction and wide-meshed character of the network is similar to that of the type of *C. retiintextum*. Strands connecting the bases of individual processes, mentioned as occurring in the type, are commonly met with in the specimens under consideration. The processes present on the covers of the archeopyle, the bases of which may be free or united by narrow strands, are so arranged as to outline three circular areas (Pl. 24, fig. 8a).

A few specimens in which the outer connecting strands are considerably flattened and highly perforated (Pl. 24, fig. 10, 11) approach *Cyclonephelium reticulosum* Gerlach (1961) from German Middle and Upper Oligocene deposits. However, the identity of this variant is being left open until more is known regarding its constancy and vertical distribution.

The present record of a species of the genus *Cyclonephelium* with a conspicuous wide-meshed ornament in Victorian Tertiary deposits immediately raises doubt as to the correctness of the somewhat hesitant identification by Deflandre & Cookson (1953) of certain Australian Tertiary specimens with the European Jurassic species *Cannosphaeropsis caulleryi* Deflandre in which the whole surface of the shell is ornamented with a wide-meshed reticulum.

What can now, almost certainly, be regarded as a misidentification is understandable considering the small number of poorly preserved specimens of the so-called *Cannosphaeropsis caulleryi* and the limited information regarding the genus *Cyclonephelium* then available.

This doubt is supported by the fact that, in many of the specimens of *Cyclonephelium retiintextum* seen during the present investigation, the unornamented central portions of the shells have been partially or almost completely obscured by the accidental turning inwards of the network of the side under observation. Furthermore, when flattened specimens similar to the one shown by Deflandre & Cookson (Pl. 7, fig. 8) are lying with the antapex uppermost the absence of the ornament from the central portions of the two surfaces cannot be discerned. The same considerations apply to the earlier, tentative identifications of *C. caulleryi* from Lower Tertiary deposits in Victoria (Cookson 1953) and the Rottnest Is. Bore, W. Australia (Cookson & Eisenack 1961).

Cyclonephelium vitilare n. sp.

(Pl. 24, fig. 1-7; holotype fig. 1, 2, P 23118)

AGE AND OCCURRENCE: Paleocene: Pebble Point Formation, SW. Victoria, at 4 ft above the base.

DESCRIPTION: Shell dorsiventral, almost circular in outline with a short, blunt, apical prominence, ornamented with slightly raised, granular lace-like expansions which extend for short distances beyond the margins. The width of the ornament differs on the two surfaces, being wider and the unornamented central portion correspondingly smaller on the 'dorsal' than on the 'ventral' surface. Additionally, the ornament of the dorsal surface narrows distally to form two rounded, hollow, antapical projections one on each side of the mid-line. The ventral surface is characterized by the larger size of the unornamented portion and the presence of two or three ± prominent, tangentially directed antapical ridges (Pl. 24, fig. 6, 7).

The cover of the archeopyle is marked into three areas by low circular ridges (Pl. 24, fig. 5). The shell-membrane is thin *c.* 1·5 μ and finely and closely granular; several V-shaped notches are evident around the edge after the removal of the archeopyle cover.

DIMENSIONS: Holotype—overall length 110 μ; overall width 98 μ, width of shell 92 μ. Range in complete specimens—overall length 98-112 μ; overall width 78-102 μ.

COMMENT: *C. vitilare* can be distinguished from the described species of *Cyclonephelium* by the dorsiventrality of the shell and the characteristic type of ornament which seems to have resulted from the flattening, fusion, and perforation of low, much-branched ridges. It is frequent in the Pebble Point Formation at 4 ft from the base.

FAMILY UNCERTAIN

Genus **Trichodinium** Eisenack & Cookson

Trichodinium hirsutum n. sp.

(Pl. 25, fig. 5-13; holotype fig. 5-7, P 23120)

AGE AND OCCURRENCE: Paleocene: Pebble Point Formation, SW. Victoria, 4 ft above base.

DESCRIPTION: Shell almost spherical with a short, straight-sided, branched apical projection, an antapical projection with slanting sides and short, hair-like, terminal branches, an equatorial girdle apparently ending at the lateral margins and a pre-cingular hoof-shaped archeopyle. Shell-membrane relatively thick *c.* 2·5 μ, ornamented with solid, simple or branched, broad-based, pointed appendages the size and number of which vary according to their position on the shell. They are longest and most numerous along the margins, especially so in the region of the girdle; shorter, well-spaced or in small groups on the dorsal surface, with a tendency towards a linear arrangement parallel to the girdle which they outline (Pl. 25, fig. 10); while on the ventral surface they are very small, sparse and apparently absent from a narrow longitudinal mid-hypothecal zone suggestive of a longitudinal furrow, which they appear to outline (Pl. 25, fig. 12, 13). The cover of the archeopyle bears three or four short, stiff appendages (Pl. 25, fig. 8). The shell-membrane of the dorsal surface is marked into irregularly-shaped areas by ridges and the confluence of appendage bases several of which together form raised thickenings (Pl. 25, fig. 11). The sculptural elements of both surfaces are in the form of unevenly-spaced granules of varying size and shape.

DIMENSIONS: Holotype—overall length *c.* 125 μ, overall width *c.* 100 μ, shell *c.* 90 × 83 μ; anterior projection *c.* 17·5 μ long, posterior projection *c.* 25 μ long. Range—overall length 100-167 μ, overall width 97-105 μ, anterior projection 25-28 μ long, posterior projection 20-30 μ long, appendages 7-25 μ long.

COMMENT: Of the previously described species of *Trichodinium*, all of which are from Cretaceous deposits, the one to which *T. hirsutum* most closely approaches is the type species *T. pellitum* Eisenack & Cookson 1960. *T. hirsutum* differs from this species in the development of an antapical as well as an apical projection, its more apparent dorsiventrality, the coarser and longer appendages and the details of wall structure.

Genus **Svalbardella** Manum

Svalbardella australina n. sp.

(Pl. 25, fig. 1-4; holotype fig. 4, P 23122)

Ceratium cf. *fusus* forma *incerta* Deflandre in Deflandre & Cookson 1955, p. 293, Pl. 8, fig. 1.

AGE AND OCCURRENCE: Paleocene: Pebble Point Formation, SW. Victoria, at 4 ft and 6 ft above the base.

DESCRIPTION: Shell fusiform, tapering gradually from an enlarged central portion with convex sides towards both apex and antapex. The left-hand wall of the antapical portion (when the shell is lying with the ventral surface uppermost) narrows suddenly at about ¾ of its length, in such a way that a small spine-like projection is developed, and then slants towards the pointed apex. The apical portion which terminates in either a bluntish or pointed tip is usually slightly longer than the corresponding antapical portion. The central part of the shell is generally entirely filled with a thin-walled capsule which narrows to varying degrees towards both ends and sometimes extends into the bases of the narrow portions of the shell (Pl. 25, fig. 2). The archeopyle is small, intercalary and basically, though not always distinctly, hexagonal with alternating long and short sides (Pl. 25, fig. 4). A clearly defined tabulation has not been evident; in a few specimens faint indications of an equatorial girdle and faintly outlined areas are present on the dorsal surface (Pl. 25, fig. 1). A large clear area, frequently evident on the ventral surface (Pl. 25, fig. 2) may possibly be related to a longitudinal furrow.

Shell-membrane thin, *c.* 0·5 μ, smooth in optical section, faintly granular in surface view; wall of capsule finely and closely granular.

DIMENSIONS: Holotype—270 μ long, 54 μ broad. Range—239-302 μ long, 40-61 μ broad.

COMMENT: The genus *Svalbardella* was created by Manum (1960) for certain fusiform shells with intercalary archeopyles, equatorial girdles, and large centrally placed ellipsoid capsules, that were recovered from a Spitsbergen deposit the age of which was assumed on several grounds to be 'Upper Paleocene to Eocene'.

S. australina, while possessing the general characters of the genus *Svalbardella*, differs from the type species *S. cooksoniae* Manum (1960) in the narrower and longer apical and antapical portions of the shell, the shape of the capsule, the ornament (granular instead of reticulate), and the fainter representation of the girdle and tabulation.

The specimen doubtfully recorded as ? *Ceratium* cf. *fusus* forma *incerta* Deflandre by Deflandre & Cookson 1955 can now be confidently assigned to *Svalbardella australina*. Although rather imperfectly preserved, it demonstrates the main features of this species. Furthermore it, also, was recovered from the Pebble Point Formation, although from a different exposure, namely on the NW. side of Point Bell at some distance from the type locality of *S. australina* SE. of Dilwyn Bay. This identification is supported by the finding of two other specimens in one of the original preparations from the same locality.

Acknowledgement

This work has been made possible by financial assistance from the Commonwealth Scientific and Industrial Research Organization.

References

Cookson, Isabel C., 1953. Records of the occurrence of *Botryococcus braunii, Pediastrum* and the Hystrichosphaeridcae in Cainozoic deposits in Australia. *Mem. Nat. Mus. Melbourne* 18: 107-123.

————, 1964. Cretaceous and Tertiary microplankton from south-eastern Australia. *Proc. Roy. Soc. Vict.* 78: 85-93.

Cookson, Isabel C., and Eisenack, A., 1961. Tertiary microplankton from the Rottnest Island Bore, Western Australia. *J. Roy. Soc. W.A.* 44: 39-47.

Deflandre, G., and Cookson, Isabel C., 1955. Fossil microplankton from Australian Late Mesozoic and Tertiary sediments. *Aust. J. Mar. Freshw. Res.* 6: 242-313.

Eisenack, A., and Cookson, Isabel C., 1960. Microplankton from Australian Lower Cretaceous sediments. *Proc. Roy. Soc. Vict.* 72: 1-10.

Gerlach, Ellen, 1961. Mikrofossilien aus den Oligozän und Miozän Nordwestdeutschlands. *N. Jb. Geol. Paläont.* 112: 143-228.

Manum, S., 1960. Some Dinoflagellates and Hystrichosphaerids from the Lower Tertiary of Spitsbergen. *Nytt Mag. Botanikk* 8: 17-25.

Explanation of Plates

All figured specimens are from 4 ft above the base of the Pebble Point Formation, except P 23123 and 23452 which are from 6 ft above.

Plate 24

Fig. 1-7—*Cyclonephelium vitilare* n. sp. × *c.* 480. 1, 2, dorsal and ventral surfaces of holotype (P 23118); 3-5, dorsal surfaces of 3 specimens showing structural variation of the ornament (P 23126-7, P 23448); 6, ventral surface of paratype (P 23119) showing antapical ridges; 7, a slightly oblique view of an antapex (P 23449).

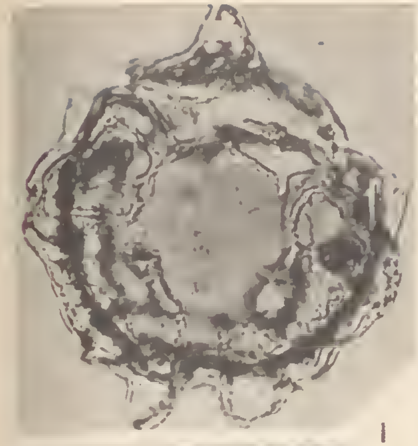
Fig. 8, 8a, 9—*Cyclonephelium retiintextum* Cookson. 8, whole specimen (P 23450) × *c.* 320; 8a, detached archeopyle cover (P 23453) × *c.* 480; 9 (P 23451) × *c.* 320.

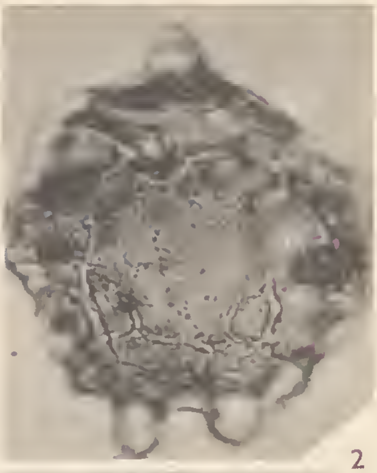
Fig. 10, 11—? cf. *Cyclonephelium reticulosum* Gerlach, shell and detached archeopyle cover of the same specimen (P 23452) × *c.* 480.

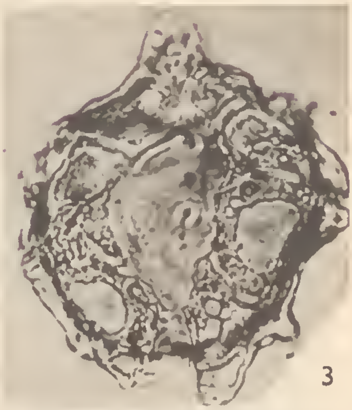
Plate 25

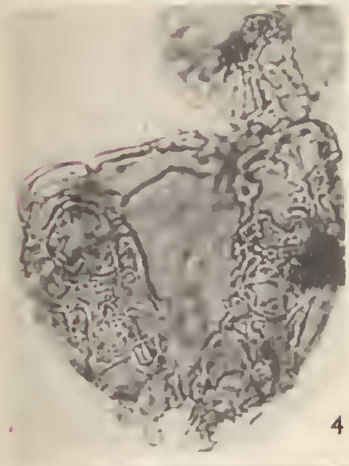
Fig. 1-4—*Svalbardella australina* n. sp. 1 (P 23125) × *c.* 330. 2, ventral surface of paratype (P 23123) × *c.* 360; 3 (P 23124) × *c.* 360; 4, holotype (P 23122) × *c.* 360.

Fig. 5-13—*Trichodinium hirsutum* n. sp. 5-7, 3 views of holotype (P 23120); 5, dorsal surface; 6, optical section; 7, ventral surface × *c.* 400; 8, dorsal surface (P 23454) × *c.* 400; 9, 10, paratype (P 23121); 9, optical section; 10, dorsal surface × *c.* 400; 11, portion of the dorsal surface of another specimen (P 23455) × *c.* 480; 12, 13, ventral surface of hypothecae of 2 specimens (P 23457, P 23456) × *c.* 480.


1

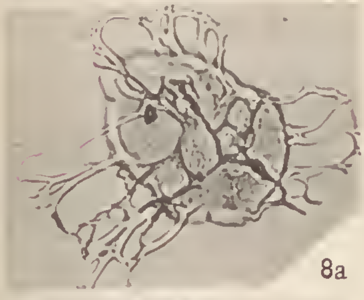

2

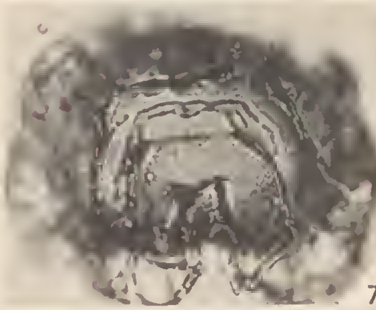

3

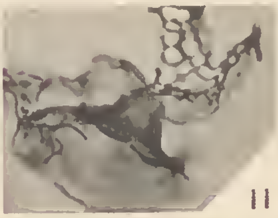

4

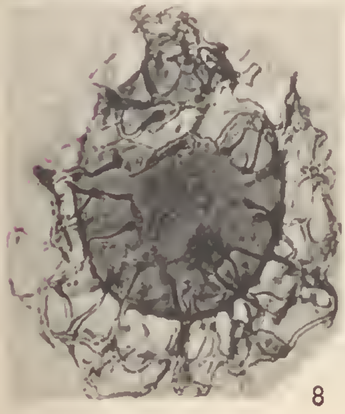

5

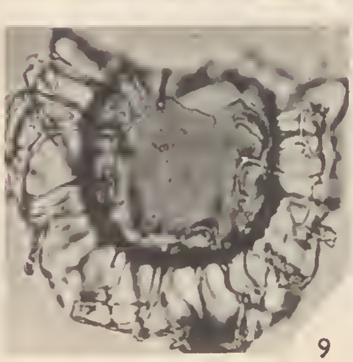

6

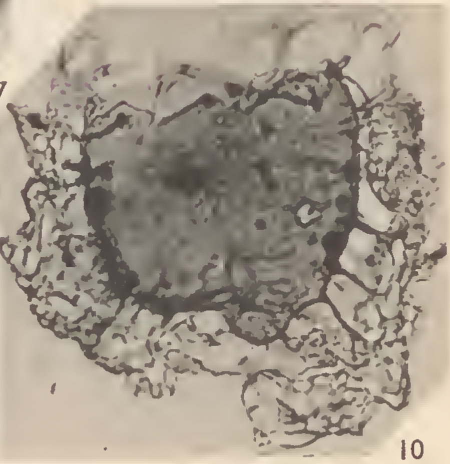

8a


7


11


8


9


10


1

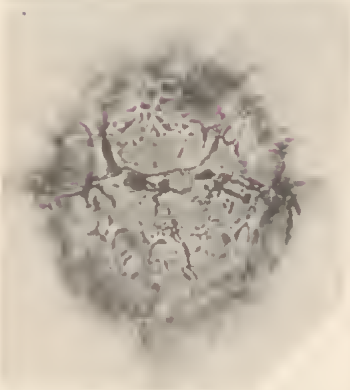

2

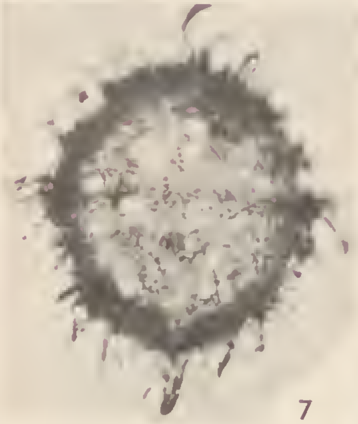

3

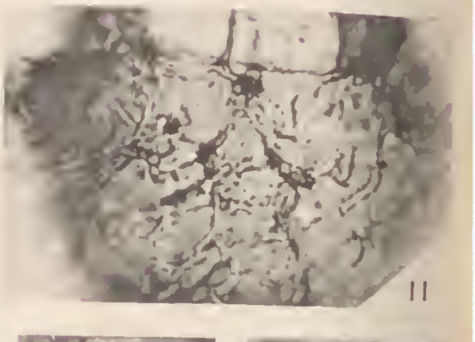

4

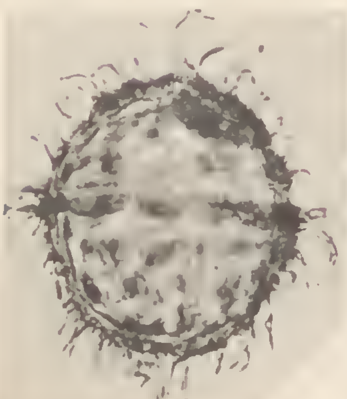

9

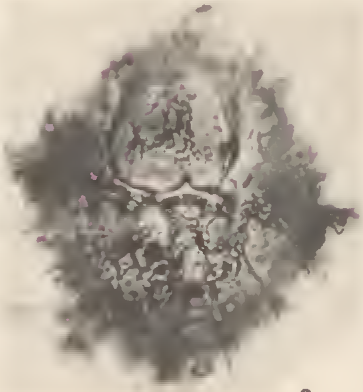

10

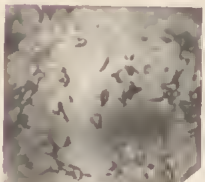

5

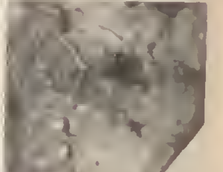

7


11


6


8


12


13

9

PRESERVATION, COMPOSITION, AND SIGNIFICANCE OF VICTORIAN LOWER TERTIARY '*CYCLAMMINA* FAUNAS'

By D. J. Taylor
Department of Mines, Melbourne, Victoria

Abstract

A thorough taxonomic examination revealed that the foraminiferal genus *Cyclammina* is not present in the Lower Tertiary sediments of W. Victoria. The much simpler arenaceous genus *Haplophragmoides* had been originally misinterpreted because of preservation features, which resulted apparently from the chemical decay of the agglutinating cement of the test material. This decay allowed a gradual replacement with coarse, loosely bonded quartz grains, so that casts were formed. Interfingering between the quartz grains and original pyritic chamber infilling gave the impression of labyrinthic internal structures and the plucking of quartz grains from the surface suggested cancellate wall structure. This process of chemical decay may be linked with the weathering of pyrite to copiapite in the sands and silts.

Detailed study showed that specific content of the Paleocene *Haplophragmoides* assemblage differs from that of the Upper Eocene and a biostratigraphic scheme was substantiated with reference to associated planktonic foraminiferal faunas. This scheme is of correlative value and has led to the conclusion that the Johanna River Sands of the Aire Coast represent an abbreviated section of the Dilwyn Clay of the Princetown area.

Some species of *Haplophragmoides* are euryhaline, and would tolerate the envisaged paralic environments of the Lower Tertiary. Species of *Cyclammina* show a preference for bathyal or near bathyal depths.

Introduction

This paper reappraises the taxonomy of the Lower Tertiary '*Cyclammina* faunas' and evaluates their stratigraphic and environmental significance. The faunas studied are of Paleocene and Eocene ages and the stratigraphic ranges of the '*Cyclammina* faunas' are based on association with planktonic foraminiferal faunas. The study will show that local correlation is possible on the distribution of species within the '*Cyclammina* faunas' where other faunas are absent. Paleocene and Eocene marine sediments are only clearly developed in W. Victoria, to the W. of Cape Otway (Fig. 1), but correlation with '*Cyclammina* faunas' in other regions of Victoria is now possible. It will be shown also that there is a relationship, on specific level, between the Lower Tertiary '*Cyclammina* faunas' and the simple arenaceous Foraminifera of the genus *Haplophragmoides* described by Taylor (1964) from the Upper Cretaceous sediments in W. Victoria.

Chapman (1904) was first to describe arenaceous Foraminifera of the genus *Cyclammina* from the Victorian Tertiary sediments. This material was in silty sands from Johanna R., 8 miles W. of Cape Otway. From this material he described 2 new species, *Cyclammina complanata* and *C. paupera*. Later, Chapman & Crespin (1930) described *Cyclammina longicompressa* and *C. rotundata* from deep borings from Gippsland, in sediments regarded as Janjukian (Oligocene). Meanwhile, Chapman (1926) had examined New Zealand Foraminifera including *Haplophragmium incisum* Stache which Chapman regarded as being a *Cyclammina*. Chapman & Crespin (1932) then recognized *C. incisa* from Victoria.

The genus *Cyclammina* has become firmly established in the Australian geological literature to include bilaterally symmetrical, planispiral, arenaceous Foraminifera from the Tertiary sediments of southern Australia. In some sediments, the

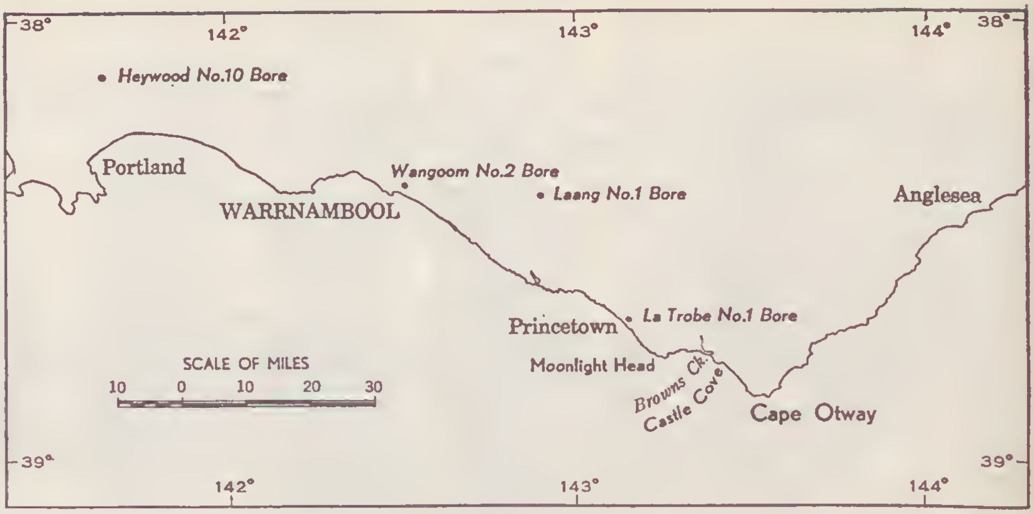


FIG. 1—Locality plan, W. Victoria.

specimens are of such a size that they are readily recognized in hand specimen. Attempts have been made to use these forms for local stratigraphic correlation (e.g. Baker 1953, Raggatt and Crespin 1955) and their presence in sediments have been interpreted to imply marine conditions when other faunas are absent.

This study has been implemented by recent drilling in W. Victoria, as subsurface samples contain well preserved '*Cyclammina* faunas' associated with planktonic foraminiferal species, while outcrop samples of the '*Cyclammina* faunas' are usually poorly preserved and seldom are associated with planktonic species.

All previously described and figured specimens of the Victorian '*Cyclammina* faunas' have been examined, either in the Commonwealth Palaeontological Collection (Bureau of Mineral Resources, Canberra) or the Palaeontological Collection in the National Museum (Melbourne). Specimens figured in this paper are housed in the Geological Survey Museum, Melbourne. The registered numbers (prefixed GSM) are given with the figure explanations.

The '*Cyclammina* Faunas'

STRATIGRAPHY OF THE '*Cyclammina*'-BEARING SEDIMENTS

Two outcropping sections of '*Cyclammina*'-bearing sediments are of particular interest:

(1) Moonlight Head to Princetown section (Baker 1953):

The basal Tertiary unit is the Pebble Point Formation of grits and sands which are ferruginized when weathered but often richly glauconitic when fresh. Above this are the silts, sandy silts, and glauconitic sands of the Dilwyn Clay. This unit contains the Rivernook Member, a glauconitic sandy clay, and the Princetown Member, a carbonaceous sandy silt, from which Baker (l.c.) reports *Cyclammina*. Many beds within the Dilwyn Clay are rich in pyrite and surface outcrops are stained by the iron sulphate, copiapite. The top of the Dilwyn Clay is not exposed.

This section is well demonstrated by continuous coring in the Mines Department's La Trobe No. 1 bore at Princetown. This bore extends below the Pebble

Point Formation into Upper Cretaceous sandy silts. These Upper Cretaceous beds are not present in surface outcrop where the Pebble Point Formation (Middle Paleocene, McGowran 1965) rests unconformably on Lower Cretaceous sediments.

(2) The Brown's Creek section (Raggatt & Crespin 1958, section 28; Carter 1958):

The basal Tertiary sands and silts rest unconformably on the Lower Cretaceous rocks. The basal unit is the Rotten Point Sands which consists of sands and grits with minor silty sands. Above this are the silty carbonaceous sands of the Johanna River Sands which are similar to part of the Dilwyn Clay. Unfortunately, there is no continuity of outcrop between the Johanna River Sands and the richly fossiliferous, Upper Eocene Brown's Creek Clays. The basal part of the Brown's Creek Clays are sandy silts which contain planktonic Foraminifera.

Driling to the W. of Princetown shows a repetition of the Moonlight Head to Princetown section with equivalents of the Brown's Creek Clays on top. In some drilled sections (e.g. Laang No. 1) the basal sandy silts are much thicker than the marls and calcareous silts which are characteristic of the Brown's Creek Clays. These Upper Eocene sandy silts often contain good '*Cyclammina* faunas'. It is noted that the lithological equivalents of the Brown's Creek Clays cannot be recognized in the La Trobe No. 1 section.

PRESERVATION

In the Moonlight Head to Princetown section the dark carbonaceous siltstones yield few if any calcareous Foraminifera. Only a few sandy horizons (e.g. the Pebble Point shell bed and the Rivernook Member) contain rich calcareous foraminiferal faunas. However, the silts contained better faunas in the La Trobe No. 1 section than did the sands. The bore samples of the silts were rich in pyrite but, in outcrop, pyrite is seldom in its original state and copiapite is present. Edwards and Baker (1951) show that weathering of pyrite results in the formation of copiapite and jarosite in the Lower Tertiary silts and sands at Anglesea (to the E. of Cape Otway). Such a reaction could release sulphuric acid which, when added to the ground water, would dissolve calcareous foraminiferal tests. This reaction is inferred from the fact that copiapite-bearing sediments seldom contain calcareous Foraminifera while identical sediments in fresh condition contain unaltered pyrite and calcareous Foraminifera.

The arenaceous '*Cyclammina* faunas' are found at several horizons in outcrop in the Princetown section but are poorly preserved and as Baker (1953) states 'cannot be isolated from the matrix without crumbling'. The term arenaceous Foraminifera suggests that they are composed of sand grains which implies that they are resistant to chemical action when compared with calcareous forms. However, the term agglutinated Foraminifera is more accurate as the tests are made up of sand grains agglutinated by an organic cementing medium. Hedley (1963) shows that the cementing medium is bonded by ferric iron and calcium. Hedley's experimental data show that agglutinated tests crumble when ferric iron and calcium is removed by use of a synthetic sequestering agent. It is assumed that this reaction takes place on weathering and/or on contact with ground water in the W. Victorian Lower Tertiary sediments and it is assumed that this reaction is linked with the decomposition of pyrite. Also of possible significance is the fact that well preserved specimens in the '*Cyclammina* faunas' are usually infilled with pyrite, while in more poorly preserved specimens the pyrite appears to be altered.

A gradual process of test decomposition and replacement can be recognized as three preservation stages which are illustrated in Fig. 2 and discussed below:

(I) The original test material (Fig. 2a). Test walls are usually fine grained and smooth. When pyrite test infilling is not present the tests exhibit chamber collapse. Original test material has only been recognized in the sands and silts in subsurface section. In calcareous sediments the original test material is common, even in outcrop specimens.

(II) Partial replacement casts (Fig. 2b, c). Outer test walls consist of a rough skin of quartz grains with a suggestion of inward quartz crystal growth which interfingers with the pyrite chamber infilling. Little if any of the original outer test wall remains, although the septa and preceding whorls are of original test material. In a single specimen this partial replacement appears to be a very gradual process,

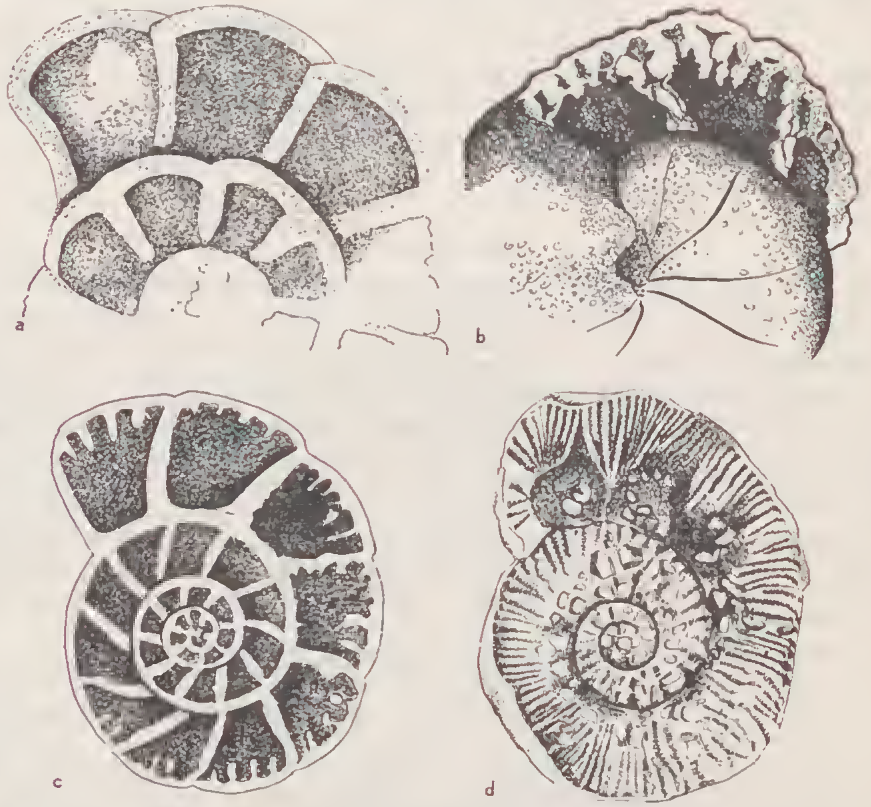


FIG. 2—Preservation stages.

a—Stage I—*Haplophragmoides complanata* (Chapman). Thick section. Diameter 0·6 mm. (GSM 60464)

b—Stage II—*H. complanata* (Chapman). Dissected specimen. Diameter 0·76 mm. (GSM 60465)

c—Stage II—*H. complanata* (Chapman). Thick section. Diameter 0·8 mm. (GSM 60466)

d—Stage III—*H.* cf. *incisa* (Stache). Thick section. Diameter 2·5 mm. (GSM 60467)

All figured specimens are from La Trobe No. 1 bore, a-c at 980 ft, d at 200 ft.

being further advanced in later chambers than in the earlier chambers of the last whorl, as is illustrated in Fig. 2c. This stage is present in both surface and sub-surface material. It is the stage of preservation of the holotypes of *Cyclammina complanata* Chapman and *C. paupera* Chapman.

(III) Ghosts or complete replacement casts (Fig. 2d) consist of grains and crystals of quartz with disseminated grains of partially altered pyrite. External suture lines are present but there is no trace of internal features such as septa. This final stage still retains cohesion as long as the specimens remain relatively undisturbed. It is the common stage in outcrop specimens as well as sub-surface samples.

In both stages II and III plucking of quartz grains from the test surface is common and this has been misinterpreted as indicating cancellated wall structure. This misinterpretation resulted in generic misidentification.

Another preservation feature is test distortion, which is taxonomically confusing at the specific level. In the more plastic marls and calcareous silts of the Upper Eocene and Oligocene, test distortion is common, especially in deep sub-surface section, no doubt due to compaction. This distortion is much more common in the arenaceous than in the calcareous Foraminifera, probably due to the structural instability of the cementing media in arenaceous forms as opposed to the crystalline structure of the calcareous forms. The direction of distortion is slightly angled to the axis of coiling with the final face asymmetrical. This preferred distortion direction may indicate a preferred burial position. Chapman and Crespin (1930) have noted apparently distorted specimens in Gippsland deep bores but, because of their abundance, have erected the species *Cyclammina longicompressa.* The author has examined many samples containing forms resembling *C. longicompressa* and considers them to be distorted forms of at least two described species.

The mode of preservation of the '*Cyclammina* faunas' made it difficult to cut thin sections. The best methods of study were found to be the cutting of thick sections, whole mounts in xylol or canada balsam, and dissection. These preparations were then drawn, as photographs lacked clarity of detail.

Generalized Test Morphology

The original test material is fine grained and externally smooth with narrow sutures. The septa are composed of fine grained material and are wider than the sutures. The pyritic chamber infilling shows clearly that the chamber walls including the septa, are simple without any labyrinthic or cancellate structures. The apertures are single equatorial marginal slits and there are no external or internal indications of multiple apertures.

Taxonomic Notes

From the generalized morphology the generic status of the '*Cyclammina* faunas' will now be discussed. Purely for convenience in discussion, the phylogenetic order at subfamily level is reversed from that given by Loeblich & Tappan (1964). The generic diagnoses are those schematically given by Mayne (1952, p. 52-53).

Family Lituolidae de Blainville 1825

Subfamily Cyclammininae Marie 1941

Genus **Cyclammina** Brady 1879

Diagnosis: Interior structure complex with alveolar hypodermis and/or labyrinthic interior structure of wall and septae. Multiple cribrate apertures with additional horizontal, interiomarginal slit at base of apertural face.

Discussion: It is evident from the generalized test morphology that the '*Cyclammina* faunas' do not comply with this diagnosis, either in interior structure or apertural detail. The quartz and pyrite interfingering of preservation stages II and III have been mistaken as alveolar hyperdermis or labyrinthic structure. Chapman (1904) described these preservation features as 'internal cancellated structure' in *Cyclammina complanata* when, in fact, it was the result of quartz plucking, as can be shown by wetting the holotype with xylol.

It is concluded that the genus *Cyclammina* is not present in the W. Victorian Lower Tertiary sediments.

Genus **Alveolophragmium** Shchedrina 1936

Diagnosis: Interior structure as for *Cyclammina*, but sutures not clearly developed. Aperture a curved interiomarginal slit at the base of the apertural face.

Discussion: Internal structural details differ from W. Victorian material.

Other genera in this subfamily differ even more radically from those discussed in respect to the '*Cyclammina* faunas'. It is apparent that the W. Victorian Lower Tertiary '*Cyclammina* faunas' are not within the Cyclammininae.

Subfamily HAPLOPRAGMOIDINAE Mayne 1952

Genus **Haplophragmoides** Cushman 1910

Diagnosis: Planispirally coiled at all stages, test more or less involute. Aperture a simple interiomarginal slit at the base of apertural face. The internal walls are simple.

Discussion: The species of the '*Cyclammina* faunas' all agree with this diagnosis and thus are all members of the genus *Haplophragmoides*.

Haplophragmoides complanata (Chapman)

(Fig. 2 a-c; 3 (1), (2))

1904 *Cyclammina complanata* Chapman, p. 228, Pl. 12, fig. 12.

Diagnosis: Somewhat compressed, discoidal, biumbilicate test, with subrounded periphery, undulate in outline. Outer whorl with 10-12 chambers with curved, narrow, slightly depressed sutures. The later chambers show an evolute tendency. Deep umbilicus. The original external wall of the test is smooth and fine grained but most specimens exhibit test replacement. The average diameter is 0·8 mm. The ratio of diameter to thickness is 5 : 2.

Discussion: This species has been ignored by workers subsequent to Chapman, apparently because it was not realized that the number of partially evolute chambers depends on the maturity of the specimen. Chapman's holotype has a maximum diameter of 1·9 mm which is unusually large, and it has 5 partially evolute final chambers. The largest specimen found by the author was 1 mm in diameter with 3 partially evolute chambers. Even the smallest specimens exhibit a tendency towards evolute coiling and this, together with the deep umbilicus, distinguishes the species from *H.* cf. *incisa* which apparently developed from *H. complanata*. This lineage is discussed below and shown on Fig. 5.

Distribution: This form is recognized only in W. Victoria. It is associated with and present above Paleocene planktonic faunas but is never associated with Upper Eocene or younger planktonic faunas. This species is not reported from the W. Victorian Upper Cretaceous faunas. Holotype from Chapman's Sample No. 1, Brown's Creek (= base Johanna River Sands).

FIG. 3

(1) a, b—*Haplophragmoides complanata* (Chapman) from La Trobe No. 1 bore at 980 ft. Diameter 0·62 mm, thickness 0·25 mm. (GSM 60456)

(2)—*H. complanata*, from ibid at 420 ft. Diameter 1 mm, thickness 0·45 mm. (GSM 60457)

(3) a, b—*Haplophragmoides* cf. *incisa* (Stache) from Laang No. 1 bore at 2150 ft. Diameter 2·1 mm. Distorted specimen. (GSM 60458)

(4) a, b—*H*. cf. *incisa* ibid. Diameter 2·1 mm, thickness 0·9 mm. (GSM 60459)

Haplophragmoides cf. **incisa** (Stache)

(Fig. 2 a; 3 (3), (4))

?1864 *Haplophragmium incisum* Stache, p. 165, Pl. 21, fig. 1.
?1926 *Cyclammina incisa* (Stache), Chapman, p. 29, Pl. 2, fig. 1.
1932 *Cyclammina incisa* Chapman & Crespin, Pl. 1, fig. 6.
1950 *Cyclammina incisa* Crespin, p. 72, Pl. 10, fig. 3.
1955 *Cyclammina incisa* Crespin, in Raggatt & Crespin, Pl. 7, fig. 3.
1930 *Cyclammina longicompressa* Chapman & Crespin, p. 97, Pl. 5, fig. 3, 384.

DIAGNOSIS: Large robust form, often visible to naked eye. External features similar to *H. complanata,* but completely involute and with a more enclosed, shallower umbilicus. Usually with roughened exterior; seldom found with original external wall.

The largest specimens are of 5 mm diameter but average diameter is of the order of 2 mm, though in some samples the average diameter is smaller. Ratio of diameter to thickness varies from 2 : 1 to 5 : 2.

DISCUSSION: On external features this species agrees with Chapman's figure of *Cyclammina incisa* (Stache) from the New Zealand Eocene and Oligocene (refer Hornibrook 1961, p. 30). As already mentioned, the Victorian material is not referable to *Cyclammina,* so the specific identification must be queried for the Victorian form. However, Hornibrook (l.c.) does cast some doubt on the generic identity of the New Zealand form.

On examination, the holotype and paratype of *C. longicompressa* were considered to be distorted specimens of *H.* cf. *incisa.* The asymmetry of the final face is significant and is illustrated in Fig. 3 (3).

H. cf. *incisa* is closely related to *H. complanata.* In considering the La Trobe No. 1 sequence (Fig. 5), specimens of *H. complanata* show an evolutionary tendency. This tendency is shown by a reduction of number of partially evolute chambers with an increase in overall size of specimens, and is linked with a gradual closing and filling of the umbilicus. Finally, all specimens at 200 ft are completely evolute and are typical of *H.* cf. *incisa.* Although specimens are not present in every sample between 1100 ft and 200 ft, it is assumed that there is a single lineage from *H. complanata* to *H.* cf. *incisa.* The segmentation of such a lineage is extremely difficult, depending on the choice of a criterion which by necessity must be regarded as arbitrary. The major evolutionary tendency, in the above lineage, is the development of a completely involute form, linked with the closing of the umbilicus. These are 2 of the 6 characters in the genus *Haplophragmoides* which are regarded as being of specific consequence by Taylor (1964, p. 563). Thus, a completely involute test is taken as the criterion for *H.* cf. *incisa,* while a partially evolute test is the criterion for *H. complanata.* But with such single forms it is imposisble to draw a sharp line of segmentation. It is predictable that there would be overlap and such is evident in the sample from 420 ft, where completely involute specimens are associated with specimens showing one partially evolute chamber. In all probability these two forms are conspecific. No one specimen in this sample can be regarded as a transition form between *H. complanata* and *H.* cf. *incisa,* but the whole sample can be regarded as a transition sample (? population) of the lineage at this level. Although theoretically incorrect, it is most convenient to list both *H. complanata* and *H.* cf. *incisa* in the 420 ft sample.

Size is another character which distinguishes *H. complanata* from the larger *H.* cf. *incisa.* This factor may be of value but is probably influenced also by environment. Generally speaking, specimens became larger as the lineage progressed.

DISTRIBUTION: *H.* cf. *incisa* is associated with Upper Eocene and younger planktonic faunas. It does range below definite Upper Eocene but is not associated with Paleocene and older faunas.

Haplophragmoides sp. **B** Taylor

(Fig. 4 (3))

1964 *Haplophragmoides* sp. *B* Taylor, p. 565, Pl. 74, fig. 4.

DIAGNOSIS: Small, fairly rotund, deeply umbilicate, loosely coiled form. 6-8 chambers in outer whorl. In some specimens, all chambers in outer whorl are partially evolute. The later or all sutures are thickened. In Tertiary specimens the maximum diameter ranges from 0·2 to 0·4 mm while in the Upper Cretaceous the maximum diameter is 0·7 mm. Ratio of diameter to thickness is 2 : 1 in Paleocene specimens.

DISCUSSION: This form may be related to *H. complanata*, but this cannot be established. *H.* sp. *B* and *H. complanata* have been found associated only in two samples, so that a suggestion that the former is an immature form of the latter cannot be clearly supported. For this reason, an informal designation has been continued, rather than giving it a valid specific designation.

DISTRIBUTION: Common throughout the W. Victorian Upper Cretaceous sequence. Has been found only at 960 ft in La Trobe No. 1 and at 2500 ft in Wangoom No. 2 bores associated with 'Rivernook faunas' (upper Paleocene).

Haplophragmoides paupera (Chapman)

(Fig. 4 (1))

1904 *Cyclammina paupera* Chapman, p. 229, Pl. 22, fig. 6.
1964 *Haplophragmoides* sp. *A* Taylor, p. 563, Pl. 74, fig. 3.

DIAGNOSIS: Delicate test with acute periphery, the final face being triangular in outline with definite apex. Deep umbilicus with prominent and flattened umbilical margin. Original test material is usually preserved even in outcrop samples. Maximum diameter of specimens ranges from 0·5 mm to 1·3 mm. Ratio of diameter to thickness is 3·5 : 1.

DISCUSSION: The acute periphery and the deep umbilicus are distinctive features. Both Upper Cretaceous and Paleocene specimens are identical with Chapman's holotype, apart from size variation. The original test material is very fine grained and chamber collapse is a common feature, so that some specimens do superficially resemble the Upper Cretaceous species *H. excavatus* Cushman & Walters.

DISTRIBUTION: Upper part of the Upper Cretaceous sequence (Taylor 1964). Also associated with Paleocene planktonic faunas but never with younger planktonic faunas. Holotype from Chapman's Sample No. 1, Brown's Creek (= base Johanna River Sands).

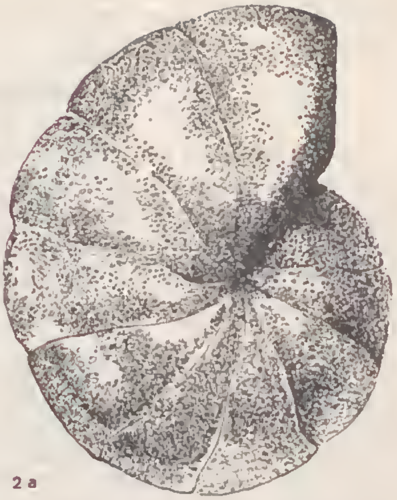
Haplophragmoides cf. **paupera** (Chapman)

(Fig. 4 (2))

1950 *Cyclammina paupera* Chapman, Crespin, p. 72, Pl. 10, fig. 4.
1955 *Cyclammina paupera* Chapman, Crespin, in Raggatt & Crespin, Pl. 7, fig. 4.

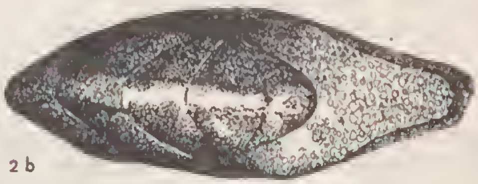
DIAGNOSIS: Compared with *H. paupera*, *H.* cf. *paupera* is a more robust, thicker, and generally larger form. The average diameter of specimens is 1·5 mm and the ratio of diameter to thickness is 3 : 1. Although this form is flattened umbilically and exhibits peripheral thinning, it does not have the prominent umbilical margin or the peripheral acuteness of *H. paupera*. The absence of the

1 a



2 a

1 b

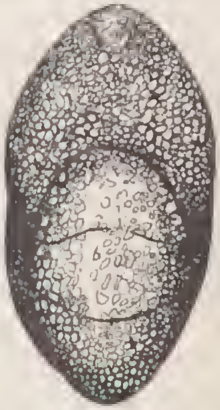


2 b

4 a

3 a

3 b



4 b

prominent umbilical margin reflects the fact that this form has a shallow closed umbilicus, compared with the deep open umbilicus of *H. paupera*. This form lacks the pseudo-keel which causes the peripheral acuteness in *H. paupera*. The original test material is never as fine-grained as that of *H. paupera*.

DISCUSSION: The differences between *H. paupera* and *H.* cf. *paupera* are morphologically a matter of degree. They are obviously parts of one lineage and this has not reached a stage where specific fragmentation can be justified on the criterion of peripheral acuteness or of umbilical features. The development seems to be towards a more globular form.

DISTRIBUTION: *H.* cf. *paupera* is associated with *H. paupera* in the Paleocene, while this form continues up into the Upper Eocene and younger sediments, where *H. paupera* is not present. This is the form illustrated by Crespin (1950) from the Demons Bluff Formation at Anglesea.

Haplophragmoides rotundata (Chapman & Crespin)

(Fig. 4 (4))

1904 *Haplophragmium latidorsatum* Chapman (non Brady), p. 227, Pl. 22, fig. 1.
1930 *Haplophragmoides rotundata* Chapman & Crespin, p. 96, Pl. 5, fig. 1, 2.
1950 *Haplophragmoides rotundata* Chapman & Crespin, p. 72, Pl. 10, fig. 5.
1955 *Haplophragmoides rotundata* Chapman & Crespin, Crespin, in Raggatt & Crespin, Pl. 7, fig. 5.
1964 *Haplophragmoides* sp. *C* Taylor, p. 564, Pl. 74, fig. 5.

DIAGNOSIS: Somewhat flattened, subglobular, completely involute test of 6-8 chambers with no umbilical hollow. External walls are usually coarse grained though occasional fine grained specimens have been noted. The average diameter of Paleocene specimens is 0·7 mm, while the larger Upper Eocene specimens are 1 mm. The ratio of diameter to thickness is 5 : 3.

DISTRIBUTION: The holotype is from Oligocene (Janjukian Stage) sediments. This species first appears in the upper part of the W. Victorian Upper Cretaceous sequence and is common throughout the Lower Tertiary and probably extends into the Miocene.

Stratigraphic Distribution of *Haplophragmoides* Assemblages

This paper is part of a study of the Lower Tertiary foraminiferal faunas sediments in W. Victoria. Extensive correlations and conclusions can only be made on considering the overall foraminiferal faunas, so that correlations and environmental interpretations made here are only preliminary until all the accumulated facts are published. A detailed faunal analysis of the La Trobe bore and other Paleocene bore sections is in progress.

'*Cyclammina*' in Victoria has been regarded as a 'facies fossil' and thus of no stratigraphic significance by some workers. 'Facies fossil' must be regarded as an invalid term as all fossils are influenced by facies. The author's work on the La Trobe

---

FIG. 4

(1) a, b—*Haplophragmoides paupera* (Chapman) from La Trobe No. 1 bore at 980 ft. Diameter 0·7 mm, thickness 0·2 mm. (GSM 60460)
(2) a, b—*H.* cf. *paupera* from Laang No. 1 bore at 2150 ft. Diameter 1·4 mm, thickness 0·5 mm. (GSM 60461)
(3) a, b—*Haplophragmoides* sp. *B* Taylor from La Trobe No. 1 bore at 960 ft. Diameter 0·3 mm, thickness 0·13 mm. (GSM 60462)
(4) a, b—*Haplophragmoides rotundata* (Chapman & Crespin) from ibid. Diameter 0·6 mm, thickness 0·25 mm. (GSM 60463)

section shows that even the planktonic Foraminifera are influenced by facies. The section on palaeoecology which follows shows that *Haplophragmoides* spp. would be expected in the envisaged environments of the Lower Tertiary of W. Victoria and that both their lateral and vertical distribution would be more constant than that of most other foraminiferal genera. Thus, any vertical distribution of species of *Haplophragmoides* would be useful in correlating sediments where they are the only forms present. However, any biostratigraphic scheme can be only of local biostratigraphic value if it is based solely on the vertical distribution of species of such a morphologically conservative genus as *Haplophragmoides*. Such a scheme is feasible only if it is based on the association of these species with species of precisely known stratigraphic range, such as planktonic Foraminifera.

Study of the La Trobe, Laang, and other bore sections shows that one assemblage of *Haplophragmoides* spp. is always associated with Paleocene planktonic Foraminifera, while a different assemblage of *Haplophragmoides* spp. is associated with Upper Eocene planktonic Foraminifera. Difficulty arises in the terminology of these associations as the one assemblage of *Haplophragmoides* spp. may occupy the same interval as several distinct assemblages of planktonic Foraminifera, as in the Upper Eocene (Carter 1958). The status of the two types of assemblages differs in that the planktonic species are widespread, while the *Haplophragmoides* spp. are of local significance only. Thus, such terms as zone or zonule should be reserved for the smaller intervals with distinct assemblages of planktonic species. For these reasons the loosely defined term '*Haplophragmoides* assemblage' is used, prefixed with time stratigraphic terms 'Paleocene' and 'Upper Eocene'. This may appear a confusion of terms, but it is emphasized that the whole scheme is based and substantiated on association with planktonic Foraminifera. The term 'Paleocene *Haplophragmoides* assemblage' is but a short way of saying 'the *Haplophragmoides* assemblage associated with Paleocene planktonic species'.

THE *Haplophragmoides* ASSEMBLAGES

THE PALEOCENE *Haplophragmoides* ASSEMBLAGE: Between 1050 and 678 ft in the La Trobe bore, a distinct assemblage of *Haplophragmoides* spp. is associated with such planktonic Foraminifera as *Globorotalia aequa* Cushman & Renz, *G. chapmani* Parr, *G. pseudomenardii* Bolli, and *G. imitata* Subbotina. McGowran (1965) has recorded these species from nearby outcrop samples and gives considerable evidence that they are of Paleocene age, probably representing the Upper Paleocene.

Fig. 5 shows that the above planktonic species are associated with a *Haplophragmoides* assemblage consisting of:

H. complanata
H. paupera
H. rotundata
H. cf. *paupera* (rare)
H. sp. *B* (one sample only).

Definite Paleocene samples from other bores (e.g. Wangoom 2 at 2500 ft, Heywood 10 at 4120 ft, and Laang 1 at 2630 ft) always contain the first 3 listed species.

THE UPPER EOCENE *Haplophragmoides* ASSEMBLAGE: Fig 5 shows that a different *Haplophragmoides* assemblage is associated with such planktonic species as *Globigeraspsis index* (Finlay), *Hantkenina alabamensis compressa* Parr, and *Pseudohastigerina micra* (Cole). Carter (1958) shows that these planktonic species

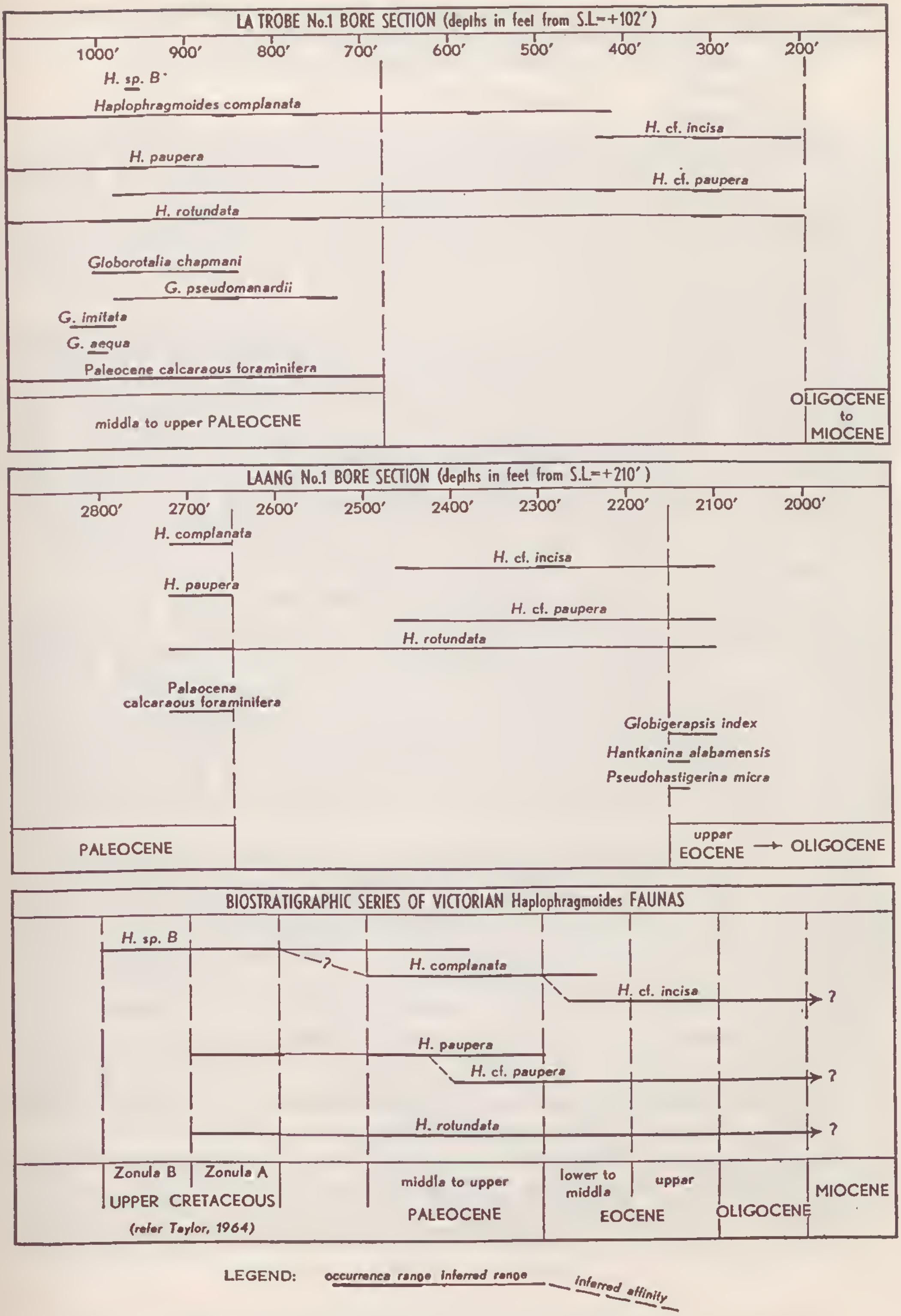


FIG. 5—Stratigraphic distribution of Lower Tertiary *Haplophragmoides* faunas in association with planktonic foraminiferal faunas.

indicate an Upper Eocene age. In the Laang 1 bore these planktonic species are associated with a *Haplophragmoides* assemblage consisting of:

H. cf. *incisa*
H. rotundata
H. cf. *paupera.*

Definite Upper Eocene outcrop samples from Brown's Creek, as well as bore samples, contain the above assemblage, though often *Haplophragmoides* spp. are rare or absent in Upper Eocene faunas which are rich in calcareous species. It is noted that this assemblage is present in the Oligocene (Janjukian Stage) and Lower Miocene. The upper limit of this fauna has not been determined. This Upper Eocene *Haplophragmoides* assemblage is present at 200 ft in the La Trobe section but planktonic species are absent.

THE *Haplopragmiodes* ASSEMBLAGE BETWEEN THE PALEOCENE AND UPPER EOCENE: As discussed in the taxonomic notes, *H.* cf. *incisa* is probably a linear development from *H. complanata* and the exact point of specific fragmentation is difficult in this lineage. This is evident at 420 ft in the La Trobe section where there is an apparent association of the two forms, together with *H. rotundata* and *H.* cf. *paupera.* But such an assemblage has not been found associated with either Paleocene or Upper Eocene planktonic Foraminifera. It is noted that Lower and Middle Eocene planktonic faunas have not been recognized in W. Victoria, although Ludbrook (1963) reported them from South Australia. At present the author does not place any stratigraphic value on the *H. complanata-H.* cf. *incisa* association, except that it occurs between definite Paleocene and definite Upper Eocene.

UPPER CRETACEOUS *Haplophragmoides* ASSEMBLAGES: Taylor (1964) has already shown a stratigraphic distribution of *Haplophragmoides* spp. in the Upper Cretaceous of W. Victoria and this is summarized in Fig. 5. It is apparent that the highest Upper Cretaceous *Haplophragmoides* assemblage is similar in specific content to the Paleocene assemblage, except that *H. complanata* is absent in the former and *H.* sp. *B* is rare in the latter. It should be noted that Taylor (l.c.) found an interval of sediment barren of Foraminifera between the highest Upper Cretaceous fauna and the lowest Tertiary fauna. This is so in the La Trobe 1, the lowest Tertiary fauna being at 1200 ft and the highest Cretaceous fauna at 1627 ft.

SUMMARY OF ASSEMBLAGES: A *Haplophragmoides* assemblage of two or more species and not an individual species is the unit of correlation in the above scheme. This is because the scheme is based on the apparent linear evolution of two groups of species in such a conservative genus as *Haplophragmoides*. These two species groups are (a) the *H. paupera* group and (b) *H. complanata* → *H.* cf. *incisa* group which may have developed from the Cretaceous species *H.* sp. *B*. The overlap of members of the one linear evolutionary group adds weight to this scheme.

Upper Cretaceous-Senonion—*H.* sp. *B* and *H paupera.*
Upper Cretaceous-post Senonian—no Foraminifera found. Could have marked development of *H.* sp. *B* → *H. complanata.*
Paleocene—Middle to Upper—*H. complanata* with very rare *H.* sp. *B*, and *H. paupera* with the more robust *H.* cf. *paupera.*
Eocene—Lower to Middle—an overlap between *H. complanata* and *H.* cf. *incisa*, and *H.* cf. *paupera* without *H. paupera.*
Upper Eocene—*H.* cf. *incisa* without *H. complanata* but with *H.* cf. *paupera.*
Oligocene to Miocene—the Upper Eocene assemblage extends upwards to at

least the Lower Miocene. The Upper Eocene age of an assemblage can be determined by the assemblage and by superposition in the section; that is, it is below the widespread Janjukian (Oligocene) limestones.

STRATIGRAPHIC CORRELATION

Correlations can now be given of outcropping sections where *Haplophragmoides* spp. are present without the association of other forms which would provide more precise correlation.

THE LA TROBE NO. 1 SECTION: This is the basic section for correlation of the *Haplophragmoides* assemblages even though definite Upper Eocene associations are absent.

MOONLIGHT HEAD TO PRINCETOWN SECTION: McGowran (1965) has shown that the Pebble Point shell bed and the Rivernook Member are Paleocene. Harris (1965), on microfloral evidence, suggests that the exposed Dilwyn Clay is of Paleocene age. Near the top of the exposed section is the Princetown Member in which Baker (1953) recorded *Cyclammina.* The author considers that this record of *Cyclammina* is, in fact, the Paleocene *Haplophragmoides* fauna and, at a later date, will provide additional evidence to show that the Princetown Member can be correlated with the 750 ft level in La Trobe 1. Between the Princetown Member and the Clifton Formation (Oligocene) the section is covered.

BROWN'S CREEK SECTION: Chapman's (1904) original material came from samples which were:

Sample No. 1—'an ochreous brown clay, almost chocolate coloured when wet' (Chapman l.c. p. 227). The sample is probably from the same horizon as Raggatt & Crespin's (1955, p. 134, section 28) 'grey to purplish brown shale with *Cyclammina*'. Chapman's sample contained *Haplophragmoides complanata* and *H. paupera* which is an assemblage regarded here as being Paleocene.

Sample No. 2—'dark brown to black pyritous and sandy clays' which contained 'few foraminiferal tests' (Chapman l.c.). This sample was probably of the highest exposed beds of the Johanna River Sands, which are in a 'washout' on the W. bank of Brown's Creek. Chapman lists nothing diagnostic in his sample, but the author has collected samples from this locality which contained poorly preserved *Haplophragmoides* spp., probably referable to the Upper Eocene assemblage. Unfortunately, the contact is covered between the Johanna River Sands and the richly fossiliferous Brown's Creek Clays of Upper Eocene age.

It is concluded that the lower part of the Johanna River Sands is Paleocene and the upper part is Upper Eocene. This would imply that the Johanna River Sands can be equated with the Dilwyn Clay between 200 ft and 1170 ft in the La Trobe section. However, Raggatt (in Raggatt & Crespin 1955, section 28) measured only 80 ft of Johanna River Sands with a 30 ft obscured interval to the overlying Brown's Creek Clays. Therefore, it would appear that the Johanna River Sands represent an abbreviated section of the Dilwyn Clay. But one has to consider that Chapman's Sample No. 1 could well be the equivalent of the Princetown Member (at 750 ft in La Trobe), and that the Brown's Creek Clays and Castle Cove Limestone (of Carter 1958) have not been recognized in the La Trobe section.

CASTLE COVE SECTION: 14 ft of Johanna River Sands underlie conformably the Upper Eocene calcareous rocks (Carter l.c.). Here the sands contain a rich assemblage of *Haplophragmoides* cf. *incisa*, *H.* cf. *paupera*, and *H. rotundata*, which strongly supports the contention that the upper part of the Johanna River Sands is of Upper Eocene age.

THE TORQUAY TO EASTERN VIEW SECTION: Although this section is on the E. side of the Otway Ra., comment is necessary in the light of Raggatt & Crespin's (l.c.) detailed study of the section. The sands and silts of the Demons Bluff Formation near the Village of Anglesea, contain a *Haplophragmoides* fauna which was figured by Crespin (1950) and refigured in Raggatt & Crespin (l.c.). On examining the figured specimens and collected samples, the author determined *H.* cf. *incisa*, *H.* cf. *paupera*, and *H. rotundata*, which are species of the Upper Eocene or younger *Haplophragmoides* assemblage. These localities are stratigraphically below the Jan Juc Limestone (Oligocene) and represent the upper part of the Demons Bluff Formation.

Mr K. J. Reed (Mines Dept unpublished report—1963/71) examined a series of shot hole samples from the Anglesea area. In a few samples of the Demons Bluff Formation he reports some where *Haplophragmoides* spp. is associated with Upper Eocene planktonic Foraminifera. The author has re-examined these samples and finds that they all contain the Upper Eocene *Haplophragmoides* assemblage.

The upper part of the Demons Bluff Formation is considered to be of Upper Eocene age.

PALAEOECOLOGY

The alteration of generic classification from *Cyclammina* to *Haplophragmoides* is of considerable palaeoecological significance and is not merely a pedantic, taxonomic exercise. Akers (1954) has presented bathymetric data to support his contention that *Cyclammina cancellata* Brady is restricted to depths greater than 200 metres in modern oceans, being most abundant below continental shelf depths. 'The species has a widespread distribution in Tertiary rocks, where its presence in conjunction with other criteria suggests an open marine depositional environment at bathyal or near bathyal depths' (Akers, l.c., abstract). Akers (l.c., p. 149) found that this statement is true of the whole genus.

If *Cyclammina* spp. were present in the Dilwyn Clay, then the above statement would contradict environmental interpretations by Baker (1953) and McGowran (1965). The consensus of opinion is that the Dilwyn Clay is a paralic sequence deposited in water which fluctuated from marine to brackish. Neglecting the reports of *Cyclammina*, the foraminiferal evidence indicates fairly shallow shelf to estuarine environments.

On the other hand, *Haplophragmoides* spp. are often represented in shelf deposits and many species of this genus are euryhaline, tolerating low salinity waters of estuarine and marsh environments as discussed by Hiltermann (1963). Therefore, the ecological distribution of *Haplophragmoides* corresponds with the apparent depositional environments of the Dilwyn Clay.

Haplophragmoides spp. are associated with Paleocene faunas in many samples from the La Trobe section. However, only in two samples are they a dominant faunal element. There is 70 per cent *Haplophragmoides* spp. at 950 ft (top of 'Rivernook Fauna') and at 750 ft (Princetown Member). This is in marked contrast with the W. Victorian Upper Cretaceous sequence where Taylor (1964) shows a dominance of this form throughout. Higher in the La Trobe section between 678 and 200 ft, *Haplophragmoides* spp. are the only species present, thus suggesting a decline in marine conditions up the section. A complete environmental study of this section is in preparation.

The depositional environment of both the Johanna River Sands and the Demons Bluff Formation is similar to that of the Dilwyn Clay, but the dominance of *Haplophragmoides* spp. could be taken to indicate that there were few, if any, marine ingressions within the former two formations. But such a statement cannot be made on outcrop evidence alone, as this paper shows that calcareous Foraminifera may not be preserved in these sediments.

Acknowledgements

This study is part of the Victorian Mines Department's investigations into the underground water and petroleum potentialities of W. Victoria. The paper is published with the permission of the Minister of Mines, the Honourable T. A. Darcy MLA.

The author thanks his colleagues in the Geological Survey for discussions on topics related to this work. Considerable acknowledgement is due to Mr K. J. Reed (now at Cornell University) for his unpublished work on the Anglesea shot hole samples. Mrs I. G. Knight assisted in all stages of this study. The author greatly appreciates her work, especially the detailed camera lucida drawings on Fig. 2-4. The final drafting of Fig. 1 and 5 was done by the Drafting Division of the Mines Department.

The author thanks the Directors of the National Museum (Melbourne) and the Bureau of Mineral Resources (Canberra) for permission to examine type material, and is grateful for assistance given by Mr E. D. Gill (National Museum) and by Dr D. J. Belford (B.M.R.).

Professor M. F. Glaessner of the University of Adelaide read the original manuscript and his comments were extremely helpful. This study was completed on the insistence of Dr B. McGowran (Adelaide University), whose detailed knowledge of the Australian Paleocene was made freely available to the author. Dr McGowran's comments on the original manuscript were of benefit, and the author is indebted to him.

References

(Including synonomy references)

AKERS, W. H., 1954. Ecologic aspects and stratigraphic significance of the foraminifer *Cyclammina cancellata*. *J. Paleont.* 28: 132-152.

BAKER, G., 1953. The relationship of the *Cyclammina*-bearing sediments to the older Tertiary deposits south-east of Princetown, Victoria. *Mem. Nat. Mus.* (*Melbourne*) 18: 125-134.

CARTER, A. N., 1958. Tertiary Foraminifera from the Aire District, Victoria. *Geol. Surv. Vict. Bull.* 55.

CHAPMAN, F., 1904. On some Cainozoic Foraminifera from Brown's Creek, Otway Coast. *Rec. Geol. Surv. Vict.* 1: 227-230.

———, 1926. Cretaceous and Tertiary Foraminifera of New Zealand. *N.Z. Geol. Surv. Pal. Bull.* 11.

CHAPMAN, F., and CRESPIN, I., 1930. Rare Foraminifera from deep borings in the Victorian Tertiaries. Part II. *Proc. Roy. Soc. Vict.* 43: 96-100.

——— ———, 1932. The Tertiary geology of the East Gippsland. *Bur. Min. Resour. Aust. Bull.* 1.

CRESPIN, I., 1950. Some Tertiary Foraminifera from Victoria. *Contri. Cushman Fdn.* 1: 70-74

EDWARDS, A. B., and BAKER, G., 1951. Some occurrences of supergene iron sulphides in relation to their environments of deposition. *J. Sed. Petr.* 21: 34-46.

HARRIS, W. K., 1965. Basal Tertiary microfloras from the Princetown area, Victoria, Australia. *Palaeontographica* B. (in press)

HEDLEY, R. H., 1963. Cement and iron in arenaceous Foraminifera. *Micropaleontology* 9: 433-441.

HILTERMANN, H., 1963. Erkennung fossiler Brackwasser-sedimente unter bessonderer Beruck-sichtigung der Foraminiferen. *Fortschr. Geol. Rheinld. Westf. Bd.* 10: 49-52.

HORNIBROOK, N. DEB., 1961. Tertiary Foraminifera from the Oamaru District (N.Z.). Part 1 Systematics and Distribution. *N.Z. Geol. Surv. Pal. Bull.* 34.

LOEBLICH, A. R., and TAPPAN, H., 1964. Protista 2—Sarcodina—chiefly 'Thecamoebians' and Foraminiferida. *Geol. Soc. Am., Treatise Invert. Paleont.* C: 1.

LUDBROOK, N. H., 1963. Correlation of the Tertiary rocks of South Australia. *Trans. Roy. Soc. S. Aust.* 87: 7-15.

MAYNC, W., 1952. Critical taxonomic study and nomenclatural revision of the Lituolidae based upon the prototype of the family, *Lituola nautiloidea* Lamarch, 1804. *Contri. Cushman Fdn.* 3: 35-55.

McGOWRAN, B., 1965. Two Paleocene foraminiferal faunas from the Wangerrip Group, Pebble Point coastal section, western Victoria. *Proc. Roy. Soc. Vict.* 79. (in press)

RAGGATT, H. G., and CRESPIN, I., 1955. Stratigraphy of the Tertiary rocks between Torquay and Eastern View, Victoria. *Proc. Roy. Soc. Vict.* 67: 75-142.

STACHE, G., 1864. Die Foraminiferen der Tertiare Mergels des Whaingaroa-Hafens (Prov. Auckland). *Novara Exped. Rept. Geol.* Theil 1.

TAYLOR, D. J., 1964. Foraminifera and the stratigraphy of the western Victorian Cretaceous sediments. *Proc. Roy. Soc. Vict.* 77: 535-603.

10

RADIOCARBON DATING AND PALAEOECOLOGY OF THE AITAPE FOSSIL HUMAN REMAINS

By P. S. Hossfeld

Fullarton, Sth Aust.

Abstract

The site near Aitape, New Guinea, where fossil human remains were collected by the writer in 1929 was revisited and materials for radiocarbon dating were collected. The associated fossils show that the ecology was mangrove swamp. Organic materials from the lenticle containing the human bones were ^{14}C dated at about 5000 years.

Introduction

The Aitape human cranial fragments (105 gm) were discovered by the writer in the Aitape District of N. New Guinea on 26 April 1929 (Nason-Jones 1930, Fenner 1941, Hossfeld 1949). They occurred in situ in a lenticle containing littoral marine molluscs and fossil coconut remains. The cranial fragments, along with fossil shells and coconut remains, were deposited in the Australian Institute of Anatomy, Canberra, on 7 November 1930. Another sample of shells was deposited in the South Australian Museum in Adelaide. At the request of Section F (Anthropology) of the Australian and New Zealand Association for the Advancement of Science, the site was revisited in May-June 1962 in order to:

(1) collect samples for radiocarbon dating, because the materials accompanying the bones were no longer available, and the sample in the S.A. Museum was too small, and

(2) re-examine the stratigraphy.

Site and Samples

The fossils were found on the bank of Paniri Ck, upstream from its junction with Kiyen Ck, about 8 miles S. of the coast and 40 miles W. by track from Aitape (approximately 03° 08′S., 141° 57′E.), where Paniri Ck emerged from the Barida Range. The elevation is about 170 ft above sea level as determined by aneroid barometer. The work was hampered by the flooding of Paniri Ck.

Marine shells, carbonized coconut fibre, and shell and wood fragments were excavated from the soft blue mudstone, cleaned, sun-dried, then packed in clean polythene bags. The work was terminated by collapse of the bank. Small collections were presented to His Honour the Administrator, Brigadier Sir Donald Cleland, to the Assistant District Officer at Aitape, and to the Holy Cross Mission at Barida.

Geomorphology

The area falls into two natural divisions—the coastal plain and the hill country of the Barida Range which rises steeply to over 2000 ft. The junction of the plain and hills is at about 170 ft and sharply defined, being a former indented shoreline. The coastal plain has a very gentle slope northwards to the sea, so that it is ill-drained and covered largely by sago-palm swamps. The creeks that drain the hills divide into numerous distributaries shortly after entering the plain, the central part of which contains the largest and worst swamps. Near the coast, the drainage waters form definite streams again.

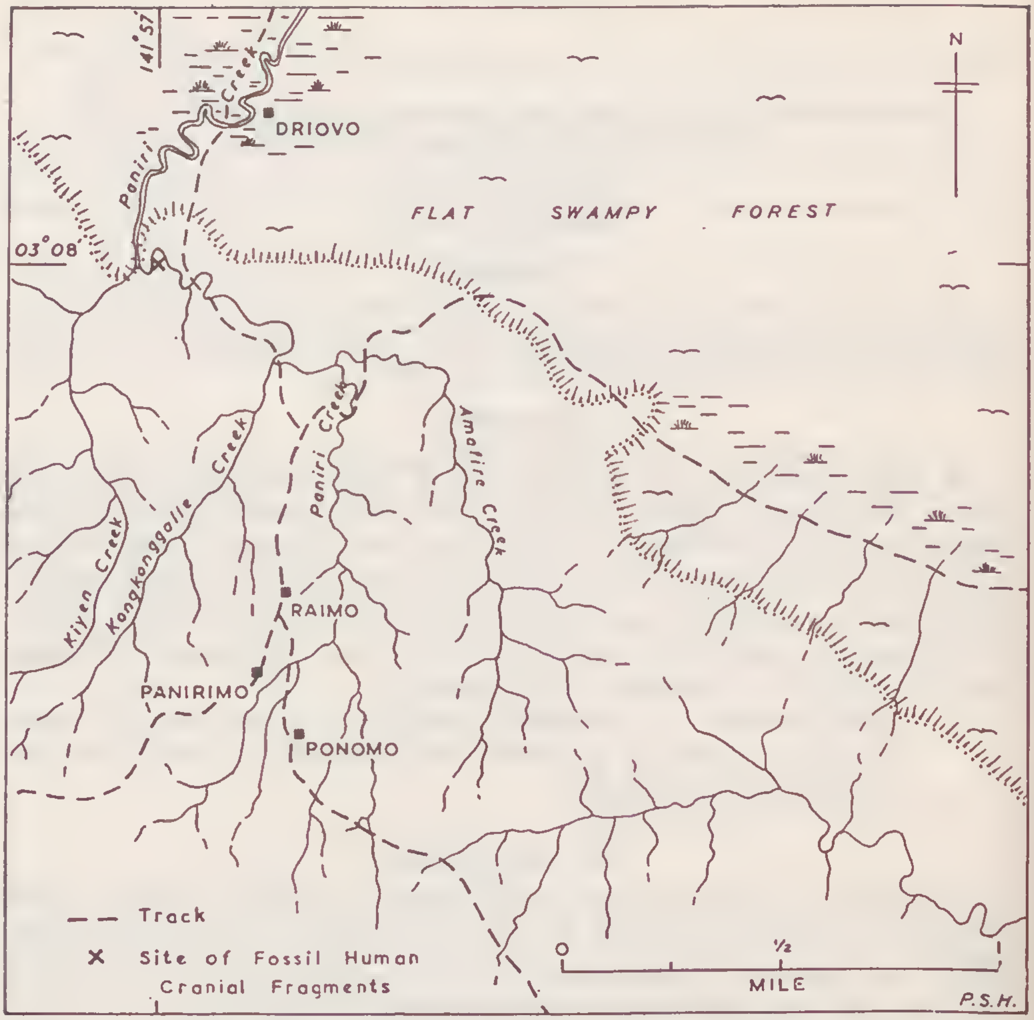


FIG. 1—Location of fossil human cranial remains W. of Aitape, New Guinea.

Geology

A general geological section of the site was given in a previous paper (Hossfeld 1949). The soft, fossiliferous mudstone that contained the human remains outcrops in most of the creeks where they leave the hills and enter the plain. Carbonized wood is present in large amounts in some places. The mudstone is blue when wet, drying to a greenish-grey, but not regaining the original colour upon re-wetting. The formation belongs to the Wanimo Group (Nason-Jones 1930). Similar formations occur more extensively in the Wanimo District, towards the W. border of New Guinea, and represent sedimentation along an emerging coastline of mangrove swamps, tidal mud-flats, and shallow bays and lagoons. These formations probably do not exceed 100 ft in thickness, and can be correlated with coralline and other calcareous deposits in the coastal region W. of Wanimo and elsewhere.

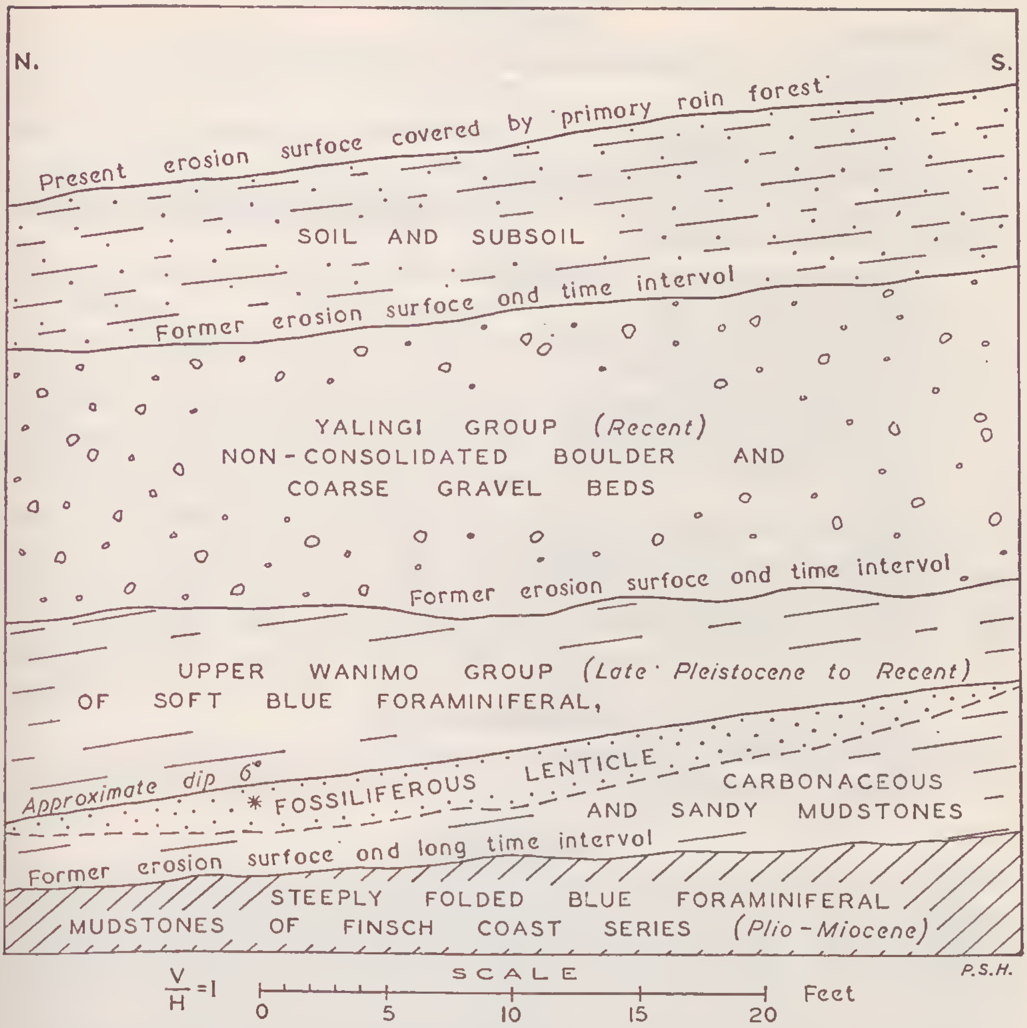


FIG. 2—Section of E. bank of Lower Paniri Ck, Aitape District, New Guinea, showing the stratigraphic relations of the mudstones in which fossil human cranial fragments were found. * Fossiliferous Lenticle: Former hollow, scoured in inter-tidal mud-flat and filled with blue, carbonaceous and sandy muds, containing human cranial fragments, coconut shell and fibre, and other plant remains, marine, intertidal and terrestrial shells and Foraminifera.

Palaeontology

Mr B. C. Cotton has identified the Mollusca collected in 1962 as follows:

PELECYPODA

Arca (*Tegillarca*) *granosa* Linnaeus
Placuna placenta Linnaeus
Dosinia sculpta Hanley
Crassostrea sp.
Cyrena coaxana Gmelin

GASTEROPODA

Telescopium telescopium Linnaeus = *fuscum* Schumacher
Melania juncea Lea
M. recta Lea
M. canaliculata Reeve
Neritina souverbiana Montrouzier

Mr A. C. Collins (through Mr E. D. Gill, National Museum of Victoria) identified the folowing Foraminifera:

? *Psammosphaera fusca testacea* Flint
Haplophragmoides sp.
Textularia cf. *sagittula* Defrance
Bulimina rostrata Brady
B. barbata Cushman
B. striata mexicana Cushman
Uvigerina sp. (*pigmea* group)
U. asperula Czjek
U. sp.
Siphogenerina virgula (Brady)
Bolivina aff. *pulchella* d'Orbigny
B. sp.
Globigerina eggeri Phumbler
G. cf. *triloba* Reuss
Orbulina universa d'Orbigny
Sphaeroidina bulloides d'Orbigny
Sphaeroidinella dehiscens (Parker and Jones)
Pullenia bulloides d'Orbigny
Globorotalia tumida (Brady)
Cibicides aff. *cicatricicosus* (Schwager).

Palaeoecology

Mr B. C. Cotton has reported that the marine molluscs are a typically Indo-Pacific mud-flat fauna. Mr A. C. Collins reported that the floatings of the specimen submitted to him contained 'fibrous vegetable matter, carbonizing on heating, similar to that found in mangrove pool deposits'. The identified Foraminifera belong to living species. 'The assemblage was dominated by three pelagic species, *Globigerina eggeri*, *G.* cf. *triloba* and *G. tumida*. Several other pelagic species were present in small numbers or as single specimens, e.g. *Sphaeroidina bulloides*, *Sphaeroidinella dehiscens*, *Orbulina universa* and *Pullenia bulloides*. None of the common shallow-water Indo-Pacific forms was present, the remaining species identified being mostly buliminc, uvigerine and rotaline forms more characteristic of offshore waters; these were comparatively rare. On the other hand, with one doubtful exception, there was none of the arenaceous benthic species normally found on mud bottoms in the deeper areas of the continental shelf; nor was there any indication of brackish water conditions.'

'The general evidence suggests that the conditions of deposition were those of a coastal mangrove swamp, probably exposed at low tide and fetid with organic matter (and hence not supporting a normal shallow-water foraminiferal fauna), inundated at intervals by water from a shallow muddy protected sea, bringing with it pelagic Foraminifera from the upper waters and some of the lighter and smaller benthic species. The absence of any rounding and polishing of grains suggests near origin and calm water conditions.'

Chronology

Four radiocarbon dates were obtained for materials in the fossilferous lenticle that contained the Aitape cranial fragments:

From D.S.I.R. Institute of Nuclear Sciences, New Zealand—

N.Z. R.1131/1	Molluscs (*Melania*)	4400 ± 85 B.P.	(2450 B.C.)
N.Z. R.1131/2	Carbonized coconut shell	4555 ± 80 B.P.	(2605 B.C.)
N.Z. R.1131/3	Carbonized wood	4915 ± 65 B.P.	(2965 B.C.)

From Gakushuin University, Tokyo, Japan—

GaK-440	Carbonized wood	5070 ± 140 B.P.	(3120 B.C.)

Besides differences in age due to the materials used, there are differences due to the conditions of deposition. Lack of recognizable bedding, and variations in thickness of the more richly fossiliferous parts of the lenticle, suggest that the ages are those of various parts of a zone 18 to 24 in. thick. The closeness of the two dates on carbonized wood assayed at different laboratories should be noted.

Dr Kenneth Oakley of the British Museum (Natural History) determined the uranium content of a fragment of the Aitape cranial remains (supplied by the Director, Australian Institute of Anatomy) as *e.* $U_3 O_8 = 8$ p.p.m. He interprets this result as indicating a late Pleistocene to Recent age. This determination and the radiocarbon dates necessitate an interpretation other than that put forward earlier (Hossfeld 1949), the events concerned having taken place in a shorter time than previously supposed. The region is thus more tectonically mobile than imagined.

Conclusion

The Aitape cranial fragments came from a lenticle representing sedimentation in a scour in a mangrove swamp, and have an age of the order of 5000 years.

Acknowledgements

The expedition was made possible by the co-operation of the Hon. Paul Hasluck, then Minister for Territories; His Honour the Administrator of Papua-New Guinea, Brigadier Sir Donald Cleland; the District Officer of Wewak, and the Assistant District Officer of Aitape, and their staffs; the friars of the Order of St Francis of Assisi, Aitape; numerous scientific colleagues, notably Mr Edmund D. Gill of the National Museum of Victoria; the friendly and devoted service of the New Guineans of Barida and Romei, including one who worked with me in 1929. The Australian Institute of Aboriginal Studies paid for two radiocarbon analyses, the Anthropological Societies of Australia paid for a third, while the author paid for the fourth.

References

FENNER, F. J., 1941. Fossil human skull fragments from Aitape, New Guinea. *Rec. S. Austr. Mus.* 6: 336-356.

HOSSFELD, P. S., 1949. The stratigraphy of the Aitape Skull, and its significance. *Trans. Roy. Soc. S. Austr.* 72: 201-207.

NASON-JONES, J., 1930. *The Geology of the Finch Coast Area.* Harrison and Sons Ltd, London.

11

A STUDY OF BLOOD CELL AGGLUTININS IN PLANT EXTRACTS

By M. L. Verso
Red Cross Blood Transfusion Service, Victorian Division

Introduction

The fact that certain plant extracts agglutinate blood cells has been known since the last century but the first to demonstrate that some possessed blood group specificity was Renkonen (1948) who tested 99 seed extracts and found 6 which selectively agglutinated some of the blood samples tested. On further study of 4 of the 6 he found that one, *Vicia craccia*, agglutinated A_1 and A_1B cells much more strongly and to a higher titre than the cells of other groups, thus indicating anti-A_1 specificity. The remainder showed anti-H specificity.

Since then, the plant kingdom has yielded a number of blood grouping reagents of which the most useful are an anti-A_1 reagent from *Dolichos biflorus,* anti-H reagents from several species of which *Ulex europeus* is the most important, anti-N reagents from *Vicia graminea* and from several *Bauhinia* species, and an anti-M reagent from *Iberus amara.* Reagents obtained from these species have largely replaced the equivalent anti-sera of animal origin for general use.

The present position of plant agglutinins in blood group serology has been ably presented in two outstanding monographs. Krüpe (1956) covered all aspects of the subject, while Mäkelä (1957) presented the results of his exhaustive studies of 1408 seed samples representing 743 Leguminosae species. Chemical and immunochemical aspects of the subject have been reviewed by Morgan and Watkins (1953) and by Boyd (1960), as well as by Krüpe.

The investigations reported here were undertaken to determine whether any useful blood grouping reagents could be obtained from the extracts of seeds available locally.

Materials and Methods

Since, with a few exceptions, useful lectins have been obtained almost entirely from among the Leguminosae, the present series of tests was confined to that family. The seeds were obtained from the National Herbarium, Melbourne. They were of varying ages and not all of them had been grown in Australia. Many of the species had been tested by other workers overseas but, for reasons to be discussed later, it was decided to test all the specimens supplied.

Preparation of Extracts

After pulverizing the seeds in a pepper mill, 10 times the quantity of 0·85 per cent saline (w/v) was added and, after mixing, the extracts were incubated for two hours at 37°C with occasional shaking. The extract was then centrifuged to obtain a clear supernatant. As far as possible all the initial tests were performed on the day the extract was prepared and, after that, the extract was stored at —20°C.

Testing Routine

As a preliminary survey each extract was tested with cells of A_1, A_2, B, and O groups, as well as cells of known M and N groups. Each extract was tested with these cells using saline, albumen, and papain techniques. Any extract which showed promising agglutination by one or more of these techniques was tested for specificity with a panel of the appropriate cells using whatever techniques were applicable. Titrations were also carried out against the cell panel.

Saline Agglutinating Tests

The saline agglutinating tests were carried out in tubes using 2 per cent suspensions of the cells in physiological saline. In performing these tests one drop of the extract was placed in the tube and one drop of the cell suspension added. The tube was allowed to stand at room temperature for 30 minutes and then centrifuged at 1500 r.p.m. for one minute. Following this, it was tapped gently with the finger to resuspend the cells and then the result was read.

Albumen Agglutinating Test

The albumen agglutinating tests were performed in tubes in the same manner as the saline agglutinating tests except that a 5 per cent suspension of cells in 30 per cent bovine albumen (Commonwealth Serum Laboratories) was used instead of a 2 per cent suspension of saline.

Papain Test

In performing the papain test the two-stage slide technique of Albrey and Simmons (1960) was used. This is probably the most sensitive of the enzyme methods.

Results

The 150 seed species tested are listed in Table 1. From the preliminary tests on these extracts only two were found to show blood group specificity. *Bauhinia candicans* and *Bauhinia petersiana* both showed anti-N specificity but the former was unstable on storage and there was insufficient available for further testing, so subsequent investigations were restricted to *Bauhinia petersiana*. In Table 2 the consolidated results of a number of quantitative experiments on that extract are presented.

A number of important points emerged from the investigation of *Bauhinia petersiana*. In the preliminary tests the use of cells suspended in albumen appeared to give specific results but, on further investigation, non-specific results were often obtained with cells suspended in this medium. No time of incubation and no particular dilution were found to be reliable in overcoming these non-specific effects. This finding is in accordance with the experience of other laboratories with anti-N reagent derived from *Bauhinia* species.

In some of the experiments the saline suspension medium used was Rous and Turner solution, a glucose-citrate solution extensively employed in blood group serology, but the results when it was used in this series were unreliable. Although N cells gave satisfactory agglutination in titres of from 32 to 128, the agglutinations with MN cells were unsatisfactory and the results were not clear cut. When, however, the cells were suspended in sodium chloride solution satisfactory, clear cut agglutinations were obtained with both MN and N cells in titres from 32 to 128. It is probable that it is the presence of either the glucose or the citrate in the Rous and Turner solution that has the inhibitory effect on the reaction. As a practical point, if a specimen of blood is received already in Rous and Turner solution, satisfactory results are obtained if the cells are centrifuged and the supernatant Rous and Turner solution removed and replaced by sodium chloride solution. The concentration of sodium chloride is not critical because cells suspended in sodium chloride solutions of from 0·85 to 1·5 gave practically identical titration scores. The thermal range had little effect on reactions for the scores showed no significant variation when the cells were tested at 0°C, 20°C, and 37°C.

Several of the seed extracts in the series gave pan-agglutination with a number of cell samples of Groups A_1, A_2, B, and O suspended in saline. In Table 3, the results of titrating these seed extracts with the various cell suspensions have been set out. It can be seen that none of them gave any significant variation in their titre score according to the cell suspension used, indicating that they had no blood group specificity.

As found in other series, notably that of Mäkelä (1957), *Crotolaria striata* showed A + B specificity. That is to say it agglutinated groups containing both the A and the B antigen.

A number of extracts gave pan-agglutination when tested with papain treated cells of Groups A_1, A_2, B, and O. Many of these reactions were weak or doubtful and, on the whole, one gained the impression that the use of papain by this technique was not of great practical assistance in these studies. The results of the tests on these papain phytagglutinins are set out in Table 4.

Summary

Extracts from seeds of 150 Leguminosae species obtained from the National Herbarium, Melbourne, were tested against a panel of human erythrocytes in an attempt to discover seeds available locally with blood group specificity.

A number of extracts agglutinated saline suspensions of all cells tested, while others agglutinated all papain-treated cells.

Bauhinia petersiana gave strong agglutination with N and MN cells suspended in saline but failed to agglutinate M cells. Thus it showed anti-N specificity.

Acknowledgement

I have much pleasure in placing on record my appreciation of the help given by the Director, Mr R. T. M. Pescott, and the staff of the National Herbarium in making available seed samples for this investigation.

References

Albrey, J. A., and Simmons, R. T., 1960. The use of a papain solution of approximately pH 3·0 in Rh testing and atypical antibody detection. *Med. J. Aust.* II: 210.

Boyd, W. C., 1960. The specificity of the non-specific. *J. Immunol.* 85: 221.

Krüpe, M., 1956. *Blutgruppenspezifische pflanzliche Eiweisskörper* (*Phytoagglutinine*). Ferdinand Enke Verlag, Stuttgart.

Mäkelä, O., 1957. Studies in hemagglutinins of Leguminosae seeds. *Ann med. exp. biol. Fenn.* 35: Suppl. 11.

Morgan, W. T. J., and Watkins, W. M., 1953. The inhibition of the haemagglutinins in plant seeds by human blood group substances and simple sugars. *Brit. J. Exp. Path.* 34: 94.

Renkonen, K. O., 1948. Studies on haemagglutinins present in seeds of some representatives of the family of Leguminosae. *Ann med. exp. biol. Fenn.* 26: 66.

Table 1

List of species tested for Lectins

1 *Acacia accuminata*
2 *A. acinacea*
3 *A. aneura*
4 *A. arabica*
5 *A. armata*
6 *A. baileyana*
7 *A. bidentata*
8 *A. brachybotrya*
9 *A. bourittii*
10 *A. buxifolia*
11 *A. cognata*
12 *A. cyclopis*
13 *A. decurrens*
14 *A. denticulosa*
15 *A. dietrichiana*
16 *A. difformis*
17 *A. diffusa*
18 *A. drummondii*
19 *A. dunnii*
20 *A. elata*
21 *A. elongata*
22 *A. falciformis*
23 *A. farnesiana*
24 *A. fimbriata*
25 *A. glaucescens*
26 *A. gilberti*
27 *A. horrida*
28 *A. implexa*
29 *A. iteaphylla*
30 *A. juniperina*
31 *A. lasiocalyx*
32 *A. ligulata*
33 *A. lineata*
34 *A. longifolia*
35 *A. longissima*
36 *A. macrodenia*
37 *A. maidenii*
38 *A. meissnerii*
39 *A. melanoxylon*
40 *A. microbotria*
41 *A. myrtifolia*
42 *A. normalis*
43 *A. notabilis*
44 *A. obtusa*
45 *A. oxycedrus*
46 *A. oswaldii*
47 *A. pendula*
48 *A. pentadenia*
49 *A. podalyrialfolia*
50 *A. pruinosa*
51 *A. pubescens*
52 *A. pycnantha*
53 *A. restiacea*
54 *A. rhetinodes*
55 *A. rigens*
56 *A. rivalis*
57 *A. rossei*
58 *A. rubida*
59 *A. rupicola*
60 *A. saligna*
61 *A. suaveolens*
62 *A. scarpioides*
63 *A. signata*
64 *A. sophorae*
65 *A. spectabilis*
66 *A. stricta*
67 *A. subporosa*
68 *A. terminalis*
69 *A. trineura*
70 *A. verniciflua*
71 *A. verticillata*
72 *A. vestita*
73 *A. victoriae*
74 *A. visco*
75 *A. wattsiana*
76 *Albizzia fastigiata*
77 *A. lophantha*
78 *A. odoratissima*
79 *Amorpha fructicosa*
80 *Baphia racemosa*
81 *Baptisia australis*
82 *Bauhinia candicans*
83 *B. petersiana*
84 *Bonjeania hirsuta*
85 *Bossiaea linophylla*
86 *Burtonia scabra*
87 *B. villosa*
88 *Brachysema lanceolatum*
89 *B. subcordatum*
90 *Caesalpinia gilliesii*
91 *Cassia artemisioides*
92 *C. costata*
93 *C. eremophila*
94 *C. floribunda*
95 *C. laevigata*
96 *C. marylandica*
97 *C. mexicana*
98 *C. nodosa*
99 *C. occidentalis*
100 *C. pleurocarpa*
101 *Carmichaelia aligera*
102 *C. sylvatica*
103 *Cercis siliquastrum*
104 *Chorisema cordata*
105 *Clianthus puniceus*
106 *C. puniceus* var. *albus*
107 *Colutea arborescens*
108 *C. cilicia*
109 *C. gracilis*
110 *C. istrea*
111 *Coronilla coronata*
112 *Cytisus everestianus*
113 *C. laburnum*
114 *C. sessiliflorus*
115 *C. supinus*
116 *C. triflorus*
117 *Crotolaria striata*
118 *Dorycnium rectum*
119 *Erythrina acanthocarpa*
120 *E. arborescens*
121 *E. caffra*
122 *E. crista-galli*
123 *E. humeana*
124 *Genista aethnensis*
125 *Gleditschia caspica*
126 *G. inermis*
127 *G. sinensis*
128 *Hardenbergia comptonia*
129 *H. monophylla*
130 *Indigofera cytisoides*
131 *Kennedya prostrata*
132 *Laburnum anagyroides* var. *alschingeri*
133 *Lathyrus venosus*
134 *Lupinus polyphyllus*
135 *Mimosa acanthocarpa*
136 *M. bahamensis*
137 *Phaseolus aureus*
138 *Priestlya hirsuta*
139 *Psoralea dentata*
140 *Robinia pseudoacacia* var. *unifolia*
141 *R. holdtii*
142 *Sesbania emerus*
143 *S. grandiflora*
144 *S. tripetii*
145 *Sophora occidentalis*
146 *S. prostrata*
147 *Swainsonia galegifolia* var. *violacea*
148 *Parkinsonia aculeata*
149 *Virgilia divaricata*
150 *Thermopsis montana*

TABLE 2

Reactions of Bauhinia petersiana

	Titre								
Cell suspension	4	8	16	32	64	128	256	512	1024
M cells (M.V.) in saline	—	—	—	—	—	—	—	—	—
MN cells (G.H.) in saline	4	4	3	3	2	—	—	—	—
MN cells in Rous & Turner solution	1	1	—	—	—	—	—	—	—
N cells (U.T.) in saline**	4	4	3	3	2	2	—	—	—
N cells in Rous & Turner solution	2	2	2	1	—	—	—	—	—
N cells in saline after removal of Rous & Turner solution	4	4	4	2	2	—	—	—	—

**Essentially the same results were obtained when N cells were suspended in 0·85%, 1·0%, 1·2%, or 1·5% saline, and when 0·85% saline was tested at 37°C, 20°C, or 4°C.

TABLE 3

Titration of Saline Pan-agglutinins

Species	Cells	Titre								
		4	8	16	32	64	128	256	512	1024
Baphia racemosa	A_1	3	1	1	—	—	—	—	—	—
	A_2	3	1	1	—	—	—	—	—	—
	B	3	1	—	—	—	—	—	—	—
	O	3	2	—	—	—	—	—	—	—
Cytisus triflorus	A_1	3	1	±	—	—	—	—	—	—
	A_2	3	3	±	±	—	—	—	—	—
	B	3	2	2	—	—	—	—	—	—
	O	3	3	—	—	—	—	—	—	—
Cytisus laburnum	A_1	3	3	—	—	—	—	—	—	—
	A_2	3	2	—	—	—	—	—	—	—
	B	3	3	—	—	—	—	—	—	—
	O	4	2	—	—	—	—	—	—	—
Erythrina acanthocarpa	A_1	4	4	4	3	—	—	—	—	—
	A_2	4	4	4	4	3	—	—	—	—
	B	4	4	4	4	2	—	—	—	—
	O	4	4	4	±	—	—	—	—	—
Erythrina arborescens	A_1	3	3	3	—	—	—	—	—	—
	A_2	3	3	1	—	—	—	—	—	—
	B	3	3	3	—	—	—	—	—	—
	O	4	3	3	—	—	—	—	—	—
Erythrina caffra	A_1	4	3	3	3	3	—	—	—	—
	A_2	4	4	4	4	3	3	1	1	—
	B	4	4	4	4	3	—	—	—	—
	O	4	4	3	3	3	3	—	—	—
Erythrina crista-galli	A_1	3	3	±	—	—	—	—	—	—
	A_2	4	4	2	—	—	—	—	—	—
	B	4	3	2	—	—	—	—	—	—
	O	4	3	3	—	—	—	—	—	—
Erythrina humeana	A_1	4	3	3	3	3	—	—	—	—
	A_2	4	4	3	3	2	2	—	—	—
	B	4	4	3	3	2	2	—	—	—
	O	4	4	4	4	3	3	—	—	—
Genista aethnensis	A_1	4	4	4	3	2	±	—	—	—
	A_2	4	4	4	3	1	±	—	—	—
	B	4	4	4	3	3	±	—	—	—
	O	4	4	4	3	3	—	—	—	—
Lathyrus venosus	A_1	4	4	3	2	—	—	—	—	—
	A_2	4	4	3	—	—	—	—	—	—
	B	4	4	3	1	—	—	—	—	—
	O	4	4	3	2	—	—	—	—	—
Phaseolus aureus	A_1	4	4	1	—	—	—	—	—	—
	A_2	4	4	1	—	—	—	—	—	—
	B	4	3	1	—	—	—	—	—	—
	O	4	3	—	—	—	—	—	—	—
Robinia pseudoacacia	A_1	4	4	2	1	—	—	—	—	—
	A_2	4	4	1	—	—	—	—	—	—
	B	4	4	2	1	—	—	—	—	—
	O	4	4	1	—	—	—	—	—	—
Robinia holdtii	A_1	4	4	4	3	2	2	—	—	—
	A_2	4	4	4	3	2	1	—	—	—
	B	4	4	4	3	2	2	—	—	—
	O	4	4	4	3	3	1	—	—	—

TABLE 4
Titration of Papian Pan-agglutinins

Species	Cells	Titre							
		4	8	16	32	64	128	256	512
Acacia cognata	A1	+	+	+	+	—	—	—	—
	A2	+	+	+	+	—	—	—	—
	B	+	+	+	+	—	—	—	—
	O	+	+	+	+	—	—	—	—
Cassia eremophila	A1	+	+	—	—	—	—	—	—
	A2	+	+	—	—	—	—	—	—
	B	+	+	—	—	—	—	—	—
	O	+	+	+	—	—	—	—	—
Cassia nodosa	A1	+	+	—	—	—	—	—	—
	A2	+	+	—	—	—	—	—	—
	B	+	+	—	—	—	—	—	—
	O	+	+	+	+	—	—	—	—
Cercis siliquastrum	A1	+	+	+	+	—	—	—	—
	A2	+	+	+	+	—	—	—	—
	B	+	+	+	+	—	—	—	—
	O	+	+	+	+	—	—	—	—
Dorycnium rectum	A1	+	+	+	+	+	—	—	—
	A2	+	+	+	+	+	—	—	—
	B	+	+	+	+	+	—	—	—
	O	+	+	+	+	+	—	—	—
Gleditschia sinensis	A1	+	—	—	—	—	—	—	—
	A2	+	+	—	—	—	—	—	—
	B	+	—	—	—	—	—	—	—
	O	+	+	+	—	—	—	—	—
Virgilia divaricata	A1	+	—	—	—	—	—	—	—
	A2	±	—	—	—	—	—	—	—
	B	±	—	—	—	—	—	—	—
	O	+	—	—	—	—	—	—	—

12

THE HOOK-CLUBS OF SOUTH-EAST AUSTRALIA

By Aldo Massola
Montrose, Victoria

Abstract

In this paper the range of distribution and the origin of a peculiar type of fighting club formerly widely used in SE. Australia, and apparently developed to nullify the guard of the parrying-shield, are discussed.

Description

Topologically, the club consists of a wooden shaft of variable length and thickness, more or less straight, and oviform to round in cross section, the head being bent at a lesser or greater angle to the shaft, much like a miner's pick, and terminating in an obtuse and slightly spatulated point. The proximal end of the shaft is variably finished, sometimes terminating in a more or less sharpened point, others having a roughening or fluting of the shaft and a terminal swelling, presumably in order to afford a better grip to the hand.

Etheridge (1893, 1897, 1898), in his studies of this weapon, concentrated on the head-end; he distinguished his varieties by the measurement of the angle formed by the head in relation to the shaft.

However, no significant information can be obtained by measuring this angle. The only constant feature of the club is the finishing-off of the proximal part of the handle, and this detail conforms to the other types of wooden clubs encountered in the same region.

The head of the hook-club is part of the root of the sapling from which the club is made, a length of the sapling being retained as the handle-shaft. It is obvious that the angle of the root would influence the angle of the club-head. Further, wood lends itself readily to the development of varieties of the one object, as the carver would obviously follow the grain or peculiarities of his medium in the fashioning of any one article. On the other hand, the shape or style of the grip is dictated either by the use to which the implement is put, or by the exigencies of tradition.

When Etheridge's varieties are systematically studied it is found that they fall readily into two groups. The first includes the heavy fighting clubs, which, allowing for the diversity of the timber from which they were made, and the angle of the root effecting the angle of the head, are of remarkable uniformity throughout the region where the parrying shield was used (Massola 1963). The second group is found outside this range. These weapons are smaller and lighter; the shaft is a flattened-oval in cross section, the head protrudes on a curve from the shaft instead of at a right angle, and both the proximal and the distal ends taper off to a fairly sharp point. They are obviously throwing clubs and, while possibly derived from the fighting clubs, cannot properly be said to be a variety of them.

Although the shape of the protruding head has sometimes been referred to as resembling the beak of the emu, to the aborigines it resembled a tooth; most of the names by which this weapon was known to them in fact do mean 'tooth' or 'toothed'. On the other hand, there is a club in the collections of the National Museum of Victoria which was made into the semblance of the head of an emu by having had eyes and representations of feathers engraved on the appropriate place on the projecting head; further, the figure of an emu was engraved on the shaft. This club originated from the 'Murrumbidgee River' and is a large and heavy weapon, but it was made with a steel tool, and the emu representation could have been due to European influences. The emu-head makes it resemble the bird-headed clubs of New Caledonia, but the resemblance is so superficial that no historical connection between the two can possibly exist.

How the club was used

According to Davidson (1936) the larger specimens are fighting clubs, the smaller are throwing clubs. However, this statement is too wide in its implications, and should only apply to the clubs encountered in the most northerly fringe of its distribution, i.e. NE. Queensland.

Roth (1909), dealing with the Rockhampton clubs, stated: 'The heavy ones never left the hand, being used for the offensive and defensive at close quarters. The light ones are thrown from a distance, but were often used for knocking over native-bears, kangaroo and other game'.

The real fighting club was not thrown. This fact is testified to by many of the early settlers and observers. Assistant Protector William Thomas (1898) for instance, referring to the aborigines of the Melbourne tribe states: 'Leonile, the most dreadful hand weapon, used in single combat only'. However, some diversity of opinion exists among the early writers as to whether the blow was struck with the pointed head or with the back of it. A study of the club reveals that both sides would be very useful in striking down an enemy, but its distribution suggests that the point or hook was developed to counter the guard of the parrying-shield, and this could well have been its main purpose. One can visualize the warrior suddenly leaping in the air and endeavouring to strike his adversary with the point of the club over the guard of the shield.

On the other hand, the point would be turned away from the victim in the case of the club being used for knocking over a wounded kangaroo and other game; thus the animal would be killed without actually ruining its flesh by driving the point of the club into it. Lang (1865) describes an irate native punishing a girl who had eloped by beating her with the club and then finishing her off by driving the point of it into the crown of her skull.

If we accept that the club was evolved to get over the defence of the parrying-shield, we may infer that the possible steps which led to the development of this remarkable weapon might have been: first, the stick fighting club, then the curved fighting club, culminating in the **Kul-luk** or heavy sword club. This was followed by the invention of the parrying-shield as a defence from it, and then the development of the hook-club to counter the shield.

Distribution	**Nomenclature**
FIGHTING CLUBS	
Victoria and New South Wales as far N. as the Tweed R., and one specimen from the Rockhampton District, Queensland.	Victoria generally: **Leonile** or **Langeel.** Gippsland, Victoria: **Darn-de-wan.** Bellingen, Clarence, and Tweed R., New South Wales: **Coupon.**
South Australia as far W. as the Lower Murray, Encounter Bay, and the Coorong.	Encounter Bay, South Australia: **Marpangyie.**

Throwing Clubs

Richmond and Upper Clarence R., New South Wales.	Richmond and Upper Clarence R., New South Wales: **Burrong** and **Paroon.**
Herbert R., Rockhampton, Moreton and Wide Bay Districts, Queensland.	Herbert R. and Rockhampton Districts, Queensland: **Bendi.** Rockhampton District: **Bi-teran** (in **Tarumbal**). Moreton and Wide Bay Districts, Queensland: **Buccan.**

Conclusions

When the localities from which the hook-clubs mentioned in the literature are plotted on a map, and this map is compared with the distribution map of the parrying-shields (Massola 1963), it will appear that the former spread over a larger part of NE. Australia than the latter. However, on closer examination, it will be found that this is not really the case, as the peripheral examples of the hook-club are smaller, much lighter in weight, and differ from the heavier type in cross section, in the angle of the head, and by having pointed extremities. They have the characteristics of the typical throwing club.

The hook-clubs occurring in the region where the parrying-shield was used are large and heavy, and even if stopped by the guard of the shield, would have delivered a shattering blow on it, thus helping to confuse and demoralize the opponent.

Thus, it will be readily apparent that, although the distribution of the hook-club was somewhat larger than that of the parrying-shield, the real fighting hook-club was only used where it had to overcome the defence of the shield.

Allowance must be made for a certain amount of cultural overlapping; the persistence of the old, and the infiltration of the new is a well known phenomenon. The importing of an object, or of an idea which is out of context in its new habitat, means that it has to be modified to suit the needs of the people, or the context changed to suit the new import. Thus, in the Rockhampton district, where no parrying-shields have been reported (although the linguistic evidence points to it having been known) the hook-club did not have to be large and heavy, and therefore assumed the function of the throwing club.

Roth (1909) stated that 'in the days before the advent of the whites' the two-handed sword-club was used in the Rockhampton district, and, according to his informant, an old man, it was called **bi-teran** in the **Tarumbal** language, the name which was also applied to the hook-club.

Lumholtz (1889), writing 20 years before Roth, had stated that wooden swords were rare, but that the hook-club was even rarer.

These statements may be taken to indicate that the hook-club was a comparatively recent introduction in this locality, and that it had supplanted the sword-club.

Bearing in mind that it does not occur on any of the islands to the N. of Australia, that it was unknown in Tasmania, and that it appears to have been a comparatively recent introduction in the NE. while well established in the SE. of the continent, it may be reasonably concluded that the hook-club was evolved in the SE. of Australia, presumably in order to counter the defence of the parrying-shield.


HERBERT R.
INGHAM
FIGHTING HOOK-CLUBS
THROWING HOOK-CLUBS
ROCKHAMPTON
WIDE BAY
MORETON BAY
BRISBANE
TWEED R.
RICHMOND R.
CLARENCE R.
NAMBUCCA R.
ADELAIDE
ENCOUNTER BAY
SYDNEY
MELBOURNE

Fig. 1

References

DAVIDSON, D. S., 1936. Australian throwing-sticks, throwing-clubs and boomerangs. *American Anthropologist* 38.

ETHERIDGE, R., Jun., 1893. On a modification of the Australian aboriginal weapon termed the Leonile, Langeel, Bendi, or Buccan, etc. *Journ. Anth. Inst.* XXIII.

————, 1897. On modification in form and ornament of the Australian aboriginal weapon, the Lil-Lil or Woggara, etc., with additional remarks on the Langeel, Leonile, or Bendi. *Intern. Archiv. fur Eth.* X.

————, 1898. Further carved boomerangs, and two varieties of the Langeel from North Queensland. *Proc. Linn. Soc. N.S.W.* 23.

LANG, G. F., 1865. *Aborigines of Australia*

LUMHOLTZ, C., 1889. *Among Cannibals*. London.

MASSOLA, A., 1963. The parrying shields of SE. Australia. *Proc. Roy. Soc. Vict.* 76.

ROTH, W. E., 1909. Fighting weapons, North Queensland. *Ethnography Bull.* 13.

THOMAS, W., 1898. *Letters from Victorian Pioneers*. Letter No. 14. Melbourne.

13

THE TERTIARY ECHINOIDS OF SOUTH-EASTERN AUSTRALIA
III STIRODONTA, AULODONTA, AND CAMARODONTA (1)

By G. M. Philip

Department of Geology, University of New England

Abstract

The following Australian Tertiary diadematacoid regular echinoids are described and figured: *Salenidia tertiaria* (Tate), *Murravechinus paucituberculatus* (Gregory) gen. nov., *Strongylocentrotus antiquus* sp. nov., *Strongylocentrotus* (?) sp., *Heliocidaris ludbrookae* sp. nov., *Zenocentrotus peregrinus* sp. nov. Also described and figured are fragments which indicate the occurrence of generically indeterminate representatives of the aulodont family Diadematidae and of the camarodont family Toxopneustidae.

Introduction

This paper continues the description of the Tertiary echinoids of SE. Australia (Philip 1963b, 1964). Included in this part are all diadematacoid regular echinoids excepting representatives of the camarodont family Temnopleuridae which will be dealt with in Part IV. The echinoid classification used in this series of papers has been outlined in detail elsewhere (Philip 1965). The continued assistance of the individuals mentioned in previous parts is gratefully acknowledged. A University of New England Research Grant has made continuation of the work possible.

Systematics

Superorder DIADEMATACEA
Order STIRODONTA Jackson
Suborder CALYCINA Gregory
Family SALENIIDAE L. Agassiz
Subfamily SALENIINAE Mortensen
Genus **Salenidia** Pomel

Salenidia Pomel 1883, p. 94.
Pleurosalenia Pomel 1883, p. 94.
Salenidia Pomel, Mortensen 1935, p. 347 (*cum synon.*).

TYPE SPECIES: *Salenia gibba* Agassiz, the first species listed by Pomel (*loc. cit.*) and apparently designated by Lambert and Thiéry (1910, p. 212). The type species of *Pleurosalenia* Pomel is *Salenia tertiaria* Tate, by monotypy.

DIAGNOSIS: Saleniinids with simple ambulacra, each plate with a large primary tubercle.

DISTRIBUTION: Lambert and Thiéry include 8 species in this genus (recognized as a subgenus of *Salenia*), which thus ranges from the Albian of Europe to the Eocene of India and Australia. The Australian species is listed by Lambert and Thiéry as occurring in the Miocene, but it is a restricted Upper Eocene form.

REMARKS: Different interpretations have been given the genus *Pleurosalenia* Pomel. After a brief diagnosis Pomel includes within the genus '*P. tertiaria* (Tate sp.) est fossile d'Australie. *S. varispinosa* W. Tomps. (non A.Ag.) paraît être du même genre et vit dans les mers actuelles'. As *S. tertiaria* is the only species definitely included in the genus, it would seem to be the type species by monotypy. Lambert and Thiéry (1910, p. 213), however, interpret *Pleurosalenia* through *S. varispinosa* (although they designate no type species) and so regard the genus as a synonym of *Salenocidaris* A. Agassiz. On the other hand Mortensen (*loc. cit.*) places *Pleurosalenia* in the synonymy of *Salenidia*, where it correctly belongs, for *S. tertiaria* cannot be distinguished from the type species of *Salenidia* (which genus has page priority in Pomel 1883) by more than specific differences.

Salenidia tertiaria (Tate)

(Pl. 26, fig. 10-15; Fig. 2 a-b)

Salenia tertiaria Tate 1877, p. 256, fig. 2 a-c.
Pleurosalenia tertiaria (Tate), Pomel 1883, p. 94.
Salenia tertiaria Tate, Duncan 1887, p. 412-13.
Salenia tertiaria Tate 1891, p. 274 (*cum synon.*).
Salenia globosa Tate 1891, p. 279.
Salenia tertiaria Tate, Bittner 1892, p. 334-4, Pl. 1, fig. 6-7.
Salenia (*Salenidia*) *tertiaria* (Tate), Lambert and Thiéry 1910, p. 212.
Salenidia tertiaria (Tate), H. L. Clark 1946, p. 304-5.
Salenidia globosa (Tate), H. L. Clark *op. cit.*, p. 305.

DIAGNOSIS: A moderately large species of *Salenidia* with an unornamented apical system, prominent primary interambulacral tubercles and wide, closely ornamented interporiferous tracts and interambulacral midzones.

TYPE SPECIMENS: Tate's original specimens were presented to the Geological Society of London and are now in the British Museum (Nat. Hist.) (BM GSL 14084). There are 5 reasonably complete specimens so labelled which may be regarded as syntypes of the species. Of these, GSL 14084a, the largest specimen which may well be the specimen figured by Tate, is selected as lectotype.

A tablet in the Tate Collection labelled '*Salenia globosa* Tate' bears the two syntypes of this nominal species. The larger, more complete of these (AUGD T275B), which agrees with the measurements originally given by Tate for the species, is here designated lectotype of *Salenia globosa* Tate.

SYNOPSIS OF MATERIAL: Some 200 specimens were examined in different collections.

DISTRIBUTION: All available specimens from SE. Australia are from the St Vincent Basin sequence, and appear to have come solely from the Tortachilla Limestone of Upper Eocene age. The species is known also from the Eucla Basin, whence it is recorded by Tate (1891) and Singleton (1941, p. 15) as occurring at Wilson's Bluff i.e. from the Wilson's Bluff Formation. Dennant and Kitson (1903) record the species from 'Ninety Mile Desert'. There are also 3 poorly preserved specimens in the National Museum Collection from the 'cliffs at Israelite Bay, southern Western Australia'.

REMARKS: This well-marked species of *Salenidia* has been described at length by Tate (1877, 1891) and Bittner (1892) so that a further detailed description is deemed unnecessary. The species is characterized particularly by the prominent interambulacral tubercles and the wide granular interporiferous tracts of the ambulacra. In these features it recalls *Salenidia blanfordi* (Duncan and Sladen 1882, p. 29-31, Pl. 6) from the Eocene of Sind, which, however, possesses a much smaller apical system in which ocular I contributes to the circlet of plates around the periproct. Duncan (1887, p. 412-3) has noted that this latter feature is occasionally seen in *S. tertiaria*, but it has not been observed in any specimen available to me. Although a considerable variation obtains in the size and number of the sutural fossettes of the apical system, the relative size and arrangement of the plates appears to be very constant, as, indeed, was found by Bittner.

Tate (1891) distinguished two species from Aldinga. The second, *S. globosa*, was distinguished from *S. tertiaria* by its larger size, 'its globose form, and having seven, in place of six, primary tubercles in each row'. In fact, the lectotype of *S. tertiaria* here chosen is a large high-tested form with 7 or more interambulacral plates in each column (Fig. 1), so that *S. globosa* must be regarded as a junior synonym of *S. tertiaria.*

However, it is evident from Tate's identifications of other specimens that he intended *tertiaria* to be applied to small flattened specimens. Many authors have noted the deceptive change in shape of the corona which accompanies the growth of saleniids. For example Cooke (1959, p. 13) observes 'Young individuals commonly appear to be more depressed than mature ones . . . As the coronal plates increase in size and number, the shape of the test becomes more nearly globular'. It would seem likely, therefore, that the larger globose forms are merely growth variants of the smaller forms with low tests.

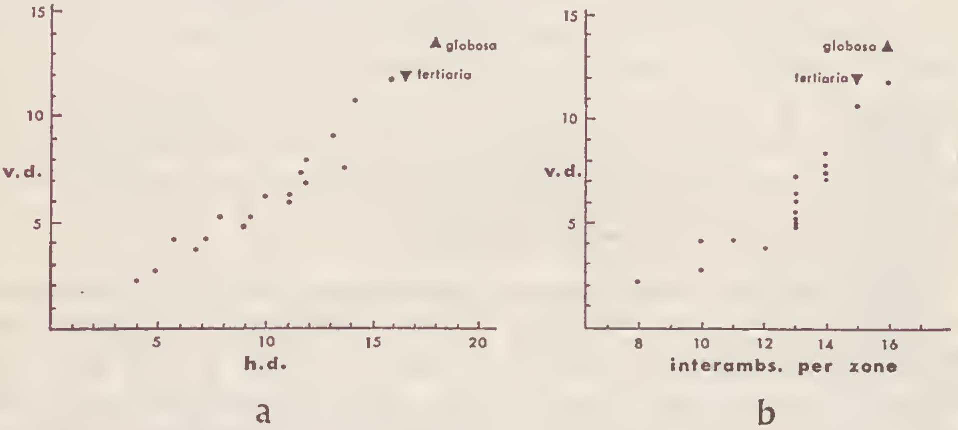


FIG. 1—Growth relationships in a collection of specimens of *Salenidia tertiaria* (Tate). Superimposed are the positions of the lectotypes of *S. tertiaria* and *S. globosa* (Tate). Based on AUGD 17010 A-R.

Sufficient material is available to give a growth series for the species. Fig. 1a shows the arithmetic plot of v.d. against h.d. and Fig. 1b is the plot of v.d. against the number of interambulacral plates in each interambulacral zone. Superimposed are the positions of the lectotypes of *S. tertiaria* and *S. globosa.* It can be seen that *S. globosa* is based on a very large specimen which shows the culmination of the growth trends exhibited by the sample. Noteworthy in Fig. 1a is the change in the ratio v.d./h.d. during growth. In small specimens it is about 0·5; in large specimens it is about 0·75.

The perignathic girdle of *S. tertiaria* consists merely of small distant, styliform auricles. Its character was originally made known by Bittner (*loc. cit.*) but *S. tertiaria* is still the only species of *Salenidia* in which the girdle has been described.

Suborder ARBACIINA Gregory

Family ARBACIIDAE Gray

Genus **Murravechinus** (Tate MS.) gen. nov.

Murravechinus Tate MS. 1888, p. 251.
Coelopleurus L. Agassiz, Gregory 1890, p. 486.
Murravechinus Tate MS. 1891, p. 272, 274; 1893, p. 191.
Coelopleurus L. Agassiz, Lambert and Thiéry 1914, p. 264. (*partim.*)
Coelopleurus L. Agassiz, Mortensen 1935, p. 605 *et seq.* (*partim.*)

TYPE SPECIES: *Coelopleurus paucituberculatus* Gregory 1890, p. 486-7, Pl. 14, fig. 4-5 (= *Murravechinus spinosus* Tate MS.).

DIAGNOSIS: A *Coelopleurus*-like form in which the subambital interambulacral plates possess greatly reduced primary tubercles so that each plate is ornamented with 2 or 3 small tubercles and smaller granules. The perignathic girdle consists of slender, distant auricles.

REMARKS: Tate (1888) originally introduced the manuscript name *Murravechinus* for this handsome arbaciid, but later (1891, p. 272) wrote that this was identical with the species which had then been described by Gregory as *Coelopleurus paucituberculatus.*

Although Gregory's original description was based on a single imperfect specimen, he noted the important distinction of this form from species of *Coelopleurus,* namely the absence of primary tubercles in the interambulacra. This peculiarity did not escape Mortensen (1935, p. 608-9, p. 612) in the compilation of his encyclopaedical monograph. He noted that this Australian species thus stood well apart from the other species included in *Coelopleurus* and 'that the species might rather form the type of a separate genus' should it prove to be as described by Gregory. Mortensen even sought to examine the type specimen which had been lodged by Gregory in the Ipswich Museum, but found that it had been lost. Topotype material now establishes that Gregory's description was accurate in all detail. Consequently Tate's MS. name *Murravechinus* is here validated as a generic category to contain this single species.

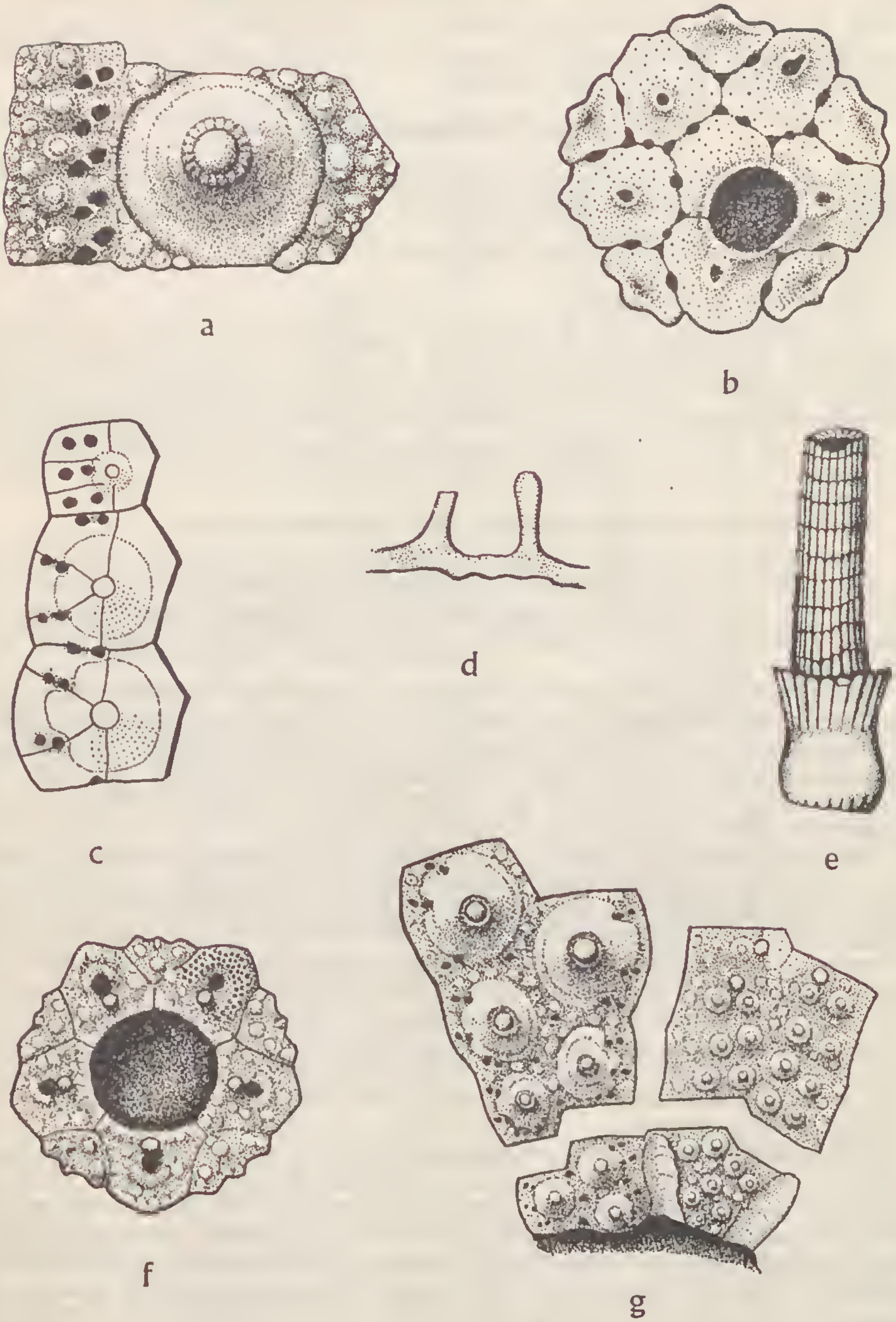
Mention should be made of the genus *Sykesia* Pomel (1883, p. 88) diagnosed as possessing 6 series of interambulacral tubercles, which would suggest close comparison with *Murravechinus.* However, *Sykesia* was based on the figures of *Coelopleurus pratti* d'Archiac (d'Archiac and Haime 1853, Pl. 13, fig. 5-6). The subsequent description and illustration of the species (Duncan and Sladen 1885, p. 254-257, Pl. 39, fig. 9-12) shows the interambulacra to possess two series of large primary tubercles as in typical species of *Coelopleurus.* Lambert and Thiéry (1914, p. 264) note 'Les tubercules secondaires du *C. Pratti* résultent seulement de la restauration d'un individu très défectueux en sorte que le genre *Sykesia* n'a aucune valeur reélle'.

The excessive enlargement of the ambulacral tubercles relative to those of the interambulacra in *Murravechinus* leads to the ambulacra being slightly wider than the interambulacra at the ambitus, unlike fossil species of *Coelopleurus.* A further outcome of this peculiarity is the fact that there are considerably more interambulacral plates than ambulacral plates in adjacent columns.

Attention may also be directed to the extremely delicate auricles of *Murravechinus* (Fig. 2d). In *Coelopleurus* the girdle, although variable, in general consists of auricles united above the ambulacra. In *Murravechinus* these are very thin processes, widely separated at their extremities. They are so delicate that they were found almost impossible to free from the soft matrix without damage.

Undoubtedly *Murravechinus* represents a specialized offshoot from *Coelopleurus*

FIG. 2—a-b *Salenidia tertiaria* (Tate). a, Ambital interambulacral plate and adjacent ambulacra column (AUGD 17012); b, Apical system (AUGD 17011), × 6. c-d, f-g, *Murravechinus paucituberculatus* (Gregory). c, Arbacioid compounding of ambital ambulacral plates. Note irregularity in position of pore-pairs in components (P 17958), × 6; d, Slightly damaged auricles (P 18321), × 10; f, Apical system (P 17955), × 6; g, Adoral terminations of an ambulacral and interambulacral zone. Note prominent 'tags' of the gill slits (P 17957), × 6. e, Diadematid gen. et sp. indet. Proximal portion of radiole (P 22308), × 6.


a
b
c
d
e
f
g

which, in middle Tertiary times, was present in India. *Coelopleurus* itself is represented in the living Australasian fauna by *C. australis* H. L. Clark, known only from Bass Strait. This is a typical species of *Coelopleurus*, very closely related to the South African *C. interruptus* Döderlein.

Murravechinus paucituberculatus (Gregory)

(Pl. 26, fig. 1-9; Fig. 2 c-d, f-g)

Coelopleurus paucituberculatus Gregory 1890, p. 486-7, Pl. 14, fig. 4-5.
Coelopleurus paucituberculatus Gregory, Tate 1891, p. 274.
Murravechinus spinosus Tate MS., *loc. cit.*
Coelopleurus paucituberculatus Gregory, Mortensen 1935, p. 608-9, p. 612; H. L. Clark 1946, p. 306.

DIAGNOSIS: As for genus.

TYPE SPECIMEN: The only described specimen to date is the holotype figured by Gregory (*loc. cit.*) from the 'banks of the Murray River at Morgan' i.e. the Morgan Limestone. Gregory states that this specimen is lodged in the Ipswich Museum. Mortensen (*loc. cit.*) instituted a search for it, but records the specimen to be lost. Mr H. E. P. Spencer, the present curator of the Ipswich Museum, at my request kindly undertook a further search for the holotype, but this was unsuccessful.

Nine topotype specimens (P 17955-63) are in the collection.

DESCRIPTION: The test is low and depressed and somewhat pentagonal in outline, with the naked area of the interambulacra extending to the ambitus. The gill-slits are very shallow, but prominent 'tags' are present extending from the margin of the peristome to opposite the base of the third ambulacral plate from the peristome (Fig. 2g).

The apical system (Fig. 2f) is comparatively small and regularly dicyclic, with the madreporite not enlarged. The genital pores are large, and a prominent granule is mounted between these and the periproct; a similar, although smaller granule is present toward the centre of each of the oculars, which appear to possess double perforations as in *Coelopleurus*. The apical system is closely yet obscurely ornamented by small, low granules as shown in Fig. 2f.

The ambulacra are relatively broad, with the primary tubercles gradually increasing in size to the ambitus. Both the ambulacral mid-zone and the adradial zone are narrow, and each bears small, low, secondary tubercles. The pores are mounted close to the adradial suture and are uniserial, although they tend to be somewhat arcuate on the larger plates. The components of the ambulacral triads are typically arbacioid in arrangement (Fig. 2c). The smooth imperforate ambulacral tubercles are large and high at the ambitus, with the well-defined margins of the areoles notched by the pore-pairs, the inner of which may even lie within the boss. Up to 7 sphaeridial pits (from which the spaeridia have been lost in all specimens) are present in each ambulacral mid-zone, arranged in series originating at the margins of the peristome.

The interambulacral plates are low, and below the ambitus each zone is ornamented with 4-6 irregular series of small tubercles, the inner of which is usually the largest and so probably represents the primary tubercle. Toward the adradial suture the tubercles are smaller and low tubercles are present covering the plates. The bare median zones of the interambulacra are slightly sunken and bordered by well-defined granules which form regular vertical series which may extend on to the oculars. On each plate a small tubercle is mounted beside the granule, on the adradial side of which are smaller tubercles.

Synopsis of Material:

From the Murray River Cliffs:

'Lower beds, Morgan', Morgan Limestone, P 17955-63, Batesfordian and Balcombian.

'Lower beds, between Wongulla and Mannum', Mannum Formation, P 18321-2, Longfordian.

Measurements:

No.	h.d.	v.d.	Diam. apical system	Diam. peri-stome	No. ambs	No. interambs
P 19756	10·0 mm	5·0 mm	3·0 mm	4·2 mm	7	11
P 19757	15·5	9·0	5·0	6·5	9	13(14)
P 19755	17·5	9·2	6·0	7·5	10	14
P 19758	19·5	9·5	6·5	—	10(11)	14

Order Aulodonta Jackson

Suborder Diademina Duncan

Family Diadematidae Gray

Gen. et sp. indet.

(Fig. 2 e)

Material and Horizon: Radiole P 22308, 'Curlewis, Vict.', horizon and age not assignable, almost certainly Miocene.

Description and Remarks: The specimen is the proximal portion of a radiole 7·5 mm long. The base is expanded, with an oblique, distinctly crenulate acetabulum and a flaring milled ring. The shaft is hollow and is marked by longitudinal grooves and distinct verticellation in which the segments tend to be horizontally aligned.

The diadematid affinities of this radiole are indicated by the hollow shaft, its verticellation and crenulate acetabulum. As diadematids constitute a significant element of present-day subtropical Australian faunas, it is surprising that this fragment is the only known indication of the occurrence of the family in the Tertiary of SE. Australia. Diadematids, however, are seldom found fossilized presumably because their imbrication leads to rapid post-mortem disintegration of the test.

Order Camarodonta Jackson

Suborder Temnopleurina Mortensen

Family Toxopneustidae Troschel

Gen. et sp. indet.

(Pl. 29, fig. 4-5)

Material and Horizon: Two test fragments, P 18865, 18868, 'Airey's Inlet', i.e. Point Addis Limestone of Janjukian age.

Description and Remarks: The larger of the two fragments (Pl. 29, fig. 5) suggests that the test of this form was low and grew to a h.d. of about 50 mm. The ambulacra are of echinoid triads in which the pore-pairs are distinctly arcuate above the ambitus. Adorally the arcs become progressively lower, the poriferous tracts are correspondingly widened and the pore-pairs triserial. The smooth imperforate primary tubercles of the ambulacra form regular vertical series, and irregularly placed secondary tubercles surround the areoles of the primary tubercles. The interambulacra also possess regular vertical series of primary tubercles with an enlarged secondary tubercle each side of the primary tubercle on each plate.

Although the absence of the peristome prevents positive identification of these fragments as belonging to a toxopneustid, there can be little doubt that this is their position. The comparatively large size of the test, together with the adoral widening of the poriferous tracts of the ambulacra, prevents comparison with Australasian Echinidae, with which otherwise the fragments could be compared. From present knowledge some general relationships with such toxopneustid genera as *Cyrtechinus, Nudechinus, Gymnechinus,* and *Lytechinus* may be suggested.

On a slightly more complete fragment than either of the present specimens Duncan and Sladen (1885, p. 315, Pl. 49, fig. 5-6) based the species *Echinus subcrenatus.* This form, from the Gáj Series of Sind, was made the type species of *Gajechinus* Lambert and Thiéry (1910, p. 242) which genus was to be distinguished by the ambulacra. In the triads of these 'la plaque mediane est reduite a l'etat de demi-plaque . . .' i.e. the form possessed echinoid triads. Mortensen (1943a, p. 292) justly complains that *Gajechinus* is the 'most ill-considered' of all Lambert and Thiéry's genera.

The present fragments, although of a larger form, appear to resemble closely '*Gajechinus*' *subcrenatus.*

Suborder ECHININA Mortensen

Family STRONGYLOCENTROTIDAE Gregory

Genus **Strongylocentrotus** Brandt

Strongylocentrotus Brandt 1835, p. 63.
Strongylocentrotus Brandt, Mortensen 1943b, p. 103 *et seq.* (*cum synon.*)

TYPE SPECIES: *Echinus* (*Strongylocentrotus*) *chlorocentrus* Brandt (= *Echinus droebachiensis* Müller), validated by Opinion 208 of The International Commission of Zoological Nomenclature.

DIAGNOSIS: Moderately large, usually thick tested, somewhat flattened echininids with polyporous ambulacra with 5 or more pore-pairs in each arc. On the adoral surface the ambulacra are of constant width and, at the margin of the peristome, are wider than the interambulacra. The apical system has oculars I and V broadly insert and a slightly enlarged madreporite. The gill slits are shallow and the perignathic girdle is of high auricles united above the ambulacra with a large foramen.

DISTRIBUTION: Mortensen (1943b) recognized 7 living species of this genus, 6 confined to the N. Pacific, and the seventh, *C. droebachiensis*, widely distributed through the Arctic Seas and southward into the N. Atlantic. In view of the remarkable variation which has been described in *S. droebachiensis*, and also in the other forms, the discrimination of the species is very difficult, and their validity highly questionable (as Mortensen admits). From the existing information no revision of these forms can be suggested, but it seems likely that only two species groups are represented in the present named forms.

Mortensen (1942, 1943b) also separated the well-marked species *S. pulcherrimus* (A. Agassiz) and *S. fragilis* Jackson respectively as the genera *Hemicentrotus* and *Allocentrotus.* It seems that these, at most, should be considered as subgenera of *Strongylocentrotus.*

As fossil, the genus has been recorded from the Miocene and Pliocene of N. America (Grant and Hertlein 1938), the Miocene of France, and Pliocene of Britain. Mortensen (1943b, p. 197) maintained that, from the published information it cannot be decided whether or not the European forms rather belong to *Heterocentrotus*. However, examination of some British material does suggest that it is correctly located in *Strongylocentrotus*, although confusion exists as to the specific identification of the British Pliocene form.

Gregory (1891) diagnosed the species *S. scaber*, based on a test fragment from the Coralline Crag of Aldborough. Subsequently (1892b) he identified a test from the same locality as *S. droebachiensis* (Müller). This specimen (SM c31548) later became the type specimen of the species *S. cotteaui* Bell (1897, p. 9). This cannot be distinguished from *S. scaber*. The fact that there are 6 pore-pairs consistently developed in the arcs of the ambulacra seems to justify the separation of this form from *S. droebachiensis* and *Heterocentrotus lividus*. The apical system is unknown, but the girdle is composed of high auricles meeting above the ambulacra with a high foramen, so that the species is best considered as belonging to *Strongylocentrotus*.

Because of the distribution of the genus, Mortensen considered it to have originated in the N. Pacific and to have migrated to the N. Atlantic in relatively recent times. The form described below, fully typical of the genus, indicates that it was established in the Australasian province in Oligocene times.

Strongylocentrotus antiquus sp. nov.

(Pl. 29, fig. 1-3; Fig. 3, 4 a, d)

Toxopneustes sp. Tate MS. (Museum label).

DIAGNOSIS: A moderate sized, low tested species of *Strongylocentrotus* with high coronal plates and 5 (rarely 6) pore-pairs in very erect arcs. The secondary ambulacral tubercles are small.

TYPE SPECIMEN: Holotype AUGD 17014, a test from the Tate Collection labelled '*Toxopneustes*, Glenforslan', i.e. from the Mannum Formation of Longfordian age.

DESCRIPTION: The test is rather small and flattened, rounded in outline, and with a small apical system and a weakly notched, slightly sunken peristome. The perignathic girdle (Fig. 4a) is typical of the genus.

The apical system (Fig. 3a) has oculars I and V broadly insert. The madreporite is enlarged, with the porous area covering most of genital 2. The genital pores are large, and the plates are obscurely ornamented by granules.

The ambulacra are about half of the width of the interambulacra, and, because the arcs are very erect, the poriferous tracts are narrow above the ambitus. There are 5 (rarely 6) pore-pairs in each arc. The primary ambulacral tubercles are relatively large, and are surrounded by a small secondary tubercles and granules. On each ambital plate the upper inner and the lower outer secondary tubercles are slightly enlarged.

The high interambulacral plates possess slightly larger, smooth, imperforate primary tubercles which form regular vertical series. Their areoles are surrounded by closely spaced secondary tubercles and granules.

MEASUREMENTS:

No.	h.d.	v.d.	Diam. apical system	Diam. peri-stome	No. ambs	No. interambs
AUGD 17014	37·0 mm	18·5 mm	7·0 mm	13·5 mm	20(21)	14(15)
P 18866	33·0	16·5	6·5	10·5	21(22)	16(17)

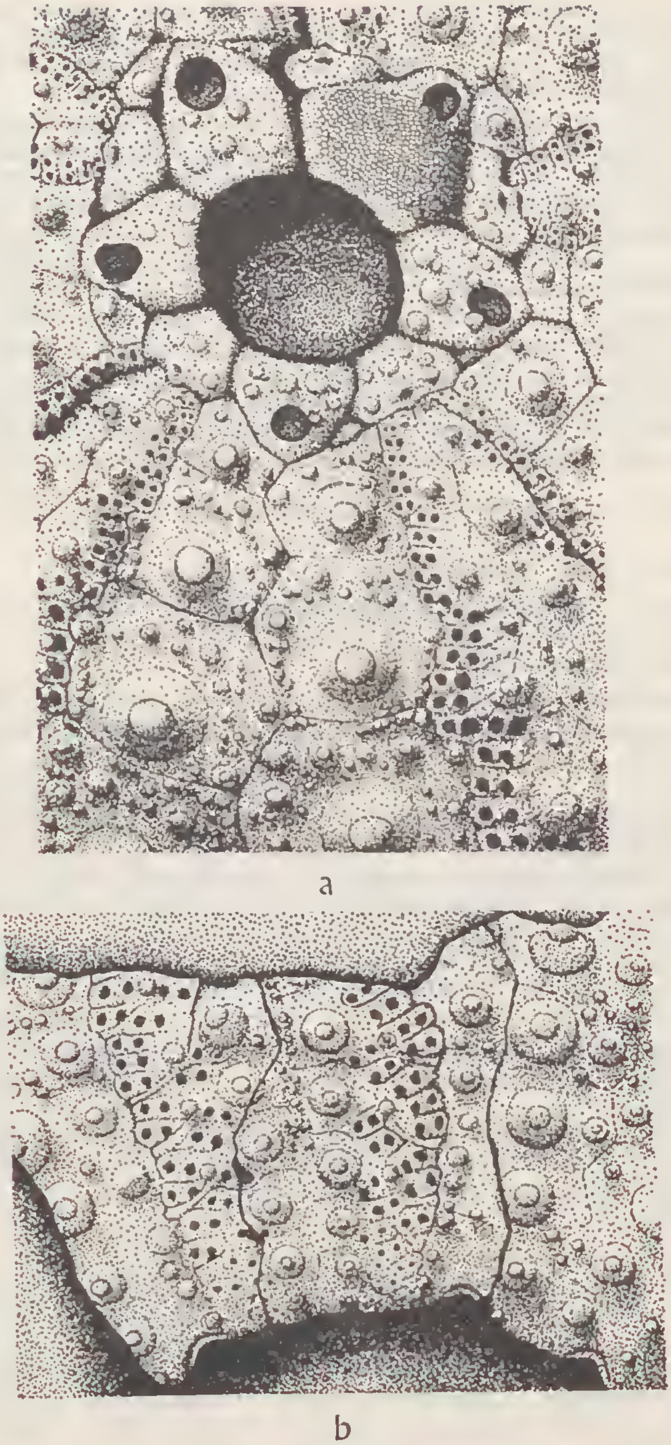


FIG. 3—*Strongylocentrotus antiquus* sp. nov. a, Apical system and adapical plates of holotype; b, Adoral termination of an ambulacral column of holotype, × 6.

SYNOPSIS OF MATERIAL:

Mannum Formation, Longfordian: Holotype and 1 test *ex* R. J. Foster Coll., 'Right bank of Murray River, 3 m. N. of Mannum'.
'Airey's Inlet', P 18866, Point Addis Limestone, Janjukian.

REMARKS: *S. antiquus* resembles the variable living species *S. droebachiensis* (Müller), but differs in the very erect arcs of the ambulacra. Thus on an ambital ambulacral plate only a single secondary tubercle occurs within the poriferous tract. This feature the species shares with *S. franciscanus* (A. Agassiz) (Mortensen 1943b, p. 244, fig. 106), but that form has considerably more pore-pairs in each arc. The character of the ambulacral ornament also seems to distinguish *S. antiquus* but this is described as being highly variable in *S. droebachiensis*.

Tate's museum label of the type specimen invites comparison of the species with toxopneustids. Although *S. antiquus* has little in common with *Toxopneustes* itself, it may be compared with species of the polyporous genus *Pseudoboletia*, particularly the living *P. atlantica* H. L. Clark. However, the echinid affinities of the species are indicated by the shallow gill slits. *S. antiquus* also resembles the polyporous echinid *Heterocentrotus*, particularly *H. lividus*, but, because of the character of the girdle and of the apical system the species must be placed in *Strongylocentrotus*.

Strongylocentrotus (?) sp.

(Pl. 29, fig. 8)

MATERIAL AND HORIZON: Test fragments from the Batesford Limestone, Longfordian or Batesfordian:

'Filter Quarry', P 18451-2; 59; 60-1; 68.
'Batesford', 3 fragments *ex* Singleton Collection.
'Ironstones above Older Basalt, just downstream from Hilbert's Pitt', P 20494 (mould of test fragment), Green Gully, Keilor, i.e. Batesfordian or Balcombian.

DESCRIPTION AND REMARKS: These fragments are all of a large, comparatively thin-tested, polyporous echinid, with 6 pore-pairs to each arc. The h.d. probably exceeded 100 mm.

The fragments thus suggest a form different from *S. antiquus*, but there is a general similarity in ornament, which suggests some relationship with this species.

It should be pointed out that generic characters of this form are not preserved; for the present, however, it may be included in *Strongylocentrotus*.

Family ECHINOMETRIDAE Gray

Genus **Heliocidaris** Agassiz and Desor

Heliocidaris L. Agassiz and Desor 1846, p. 371.
Heliocidaris L. Agassiz and Desor, Mortensen 1943b, p. 335 *et seq.* (*cum synon.*).

TYPE SPECIES: *Echinus omalostroma* Valenciennes (= *Echinus tuberculatus* Lamarck), by elimination.

DIAGNOSIS: Large, hemispherical, robust echinids which have a rounded outline, and polyporous ambulacra with 7 or more pore-pairs to each plate. The arcs may be irregularly double, and the expanded poriferous tracts of the flattened adoral surface are petalloid. The gill slits are shallow.

DISTRIBUTION: Mortensen (1943b) includes in the genus the two well-marked Australian species *H. tuberculata* (Lamarck) and *H. erythrogramma* (Valenciennes). Both these are widely distributed around the Australian coast.

Fossil representatives of the genus have not been described previously, although Fell (1953, p. 246) records 'some Echinometrid, possibly *Heliocidaris*' from the Eocene of New Zealand.

Heliocidaris ludbrookae sp. nov.

(Pl. 27, fig. 1-4, Pl. 28, fig. 1-2; Fig. 4 c)

DIAGNOSIS: A large species of *Heliocidaris* which possesses up to 12 pore-pairs, arranged in 2 irregular arcs, in each compound ambulacral plate.

TYPE SPECIMEN: Holotype AUGD 17015 (*ex* MDSA F46/55), 'Sec. 519 Hd. Finnis, Lower member, Mannum Formation', i.e. Longfordian.

DESCRIPTION: The large test is thick, rounded in outline, and very flattened on the adoral surface.

On the adapical surface the irregular arcs of the pore-pairs are comparatively erect, with up to 8 pore-pairs in an outer arc and 3 to 5 in a very irregular inner arc. Toward the ambitus there are usually 10 to 12 pore-pairs to each plate. On the adoral surface the arcs become very low and the poriferous tracts are widened and petalloid, attaining almost thrice the width of the interporiferous tracts. The primary ambulacral tubercles are moderately large, their areoles surrounded by closely spaced secondary tubercles and granules. Toward the ambitus an enlarged secondary tubercle occurs at the inner angle of each plate, and another is usually present within the poriferous tract between the inner and outer arcs. Below the ambitus the primary tubercles decrease markedly in size.

The interambulacra possess regular vertical series of moderately large, smooth primary tubercles, which are joined by very irregular inner and outer series of enlarged secondary tubercles towards the ambitus. On the adoral surface the tubercles are greatly reduced in size, but the primary tubercles continue as a regular series to the peristome. The outer series of enlarged primary tubercles may be traced to the peristome, but the inner two series tend to merge and be lost half way to the peristome.

MEASUREMENTS OF HOLOTYPE:

h.d.	v.d.	Diam. apical system	Diam. peristome	No. ambs	No. interambs
101 mm	45 mm	19·5 mm	26 mm	20(21)	26(28)

SYNOPSIS OF MATERIAL: Beside the holotype, the species is represented by the following test fragments from the Batesford Limestone:

'Filter Quarry, Batesford', P 18448; 50; 53-4; 56; 62; 64-5; 67; 71-2; 75; 77-8.
'Upper Quarry', P 19784-5.
'Batesford', 6 test fragments *ex* Singleton Collection.

REMARKS: Also present from the Batesford Limestone are a number of diadematacoid radioles which in all probability belong to this species. They are up to 30 mm long with tapering cylindrical shafts and prominent bases with expanded and oblique milled rings. The group of radioles is P 19637-51, from the Middle Quarry at Batesford. Four of these radioles are illustrated in Pl. 27, fig. 5.

The large size of this form, coupled with the irregular doubling of the arcs of the ambulacra, serve to distinguish it from the living species of the genus. Doubling of the ambulacral arcs is only very incipiently developed in the living species, and is known principally in the genus *Heterocentrotus*.

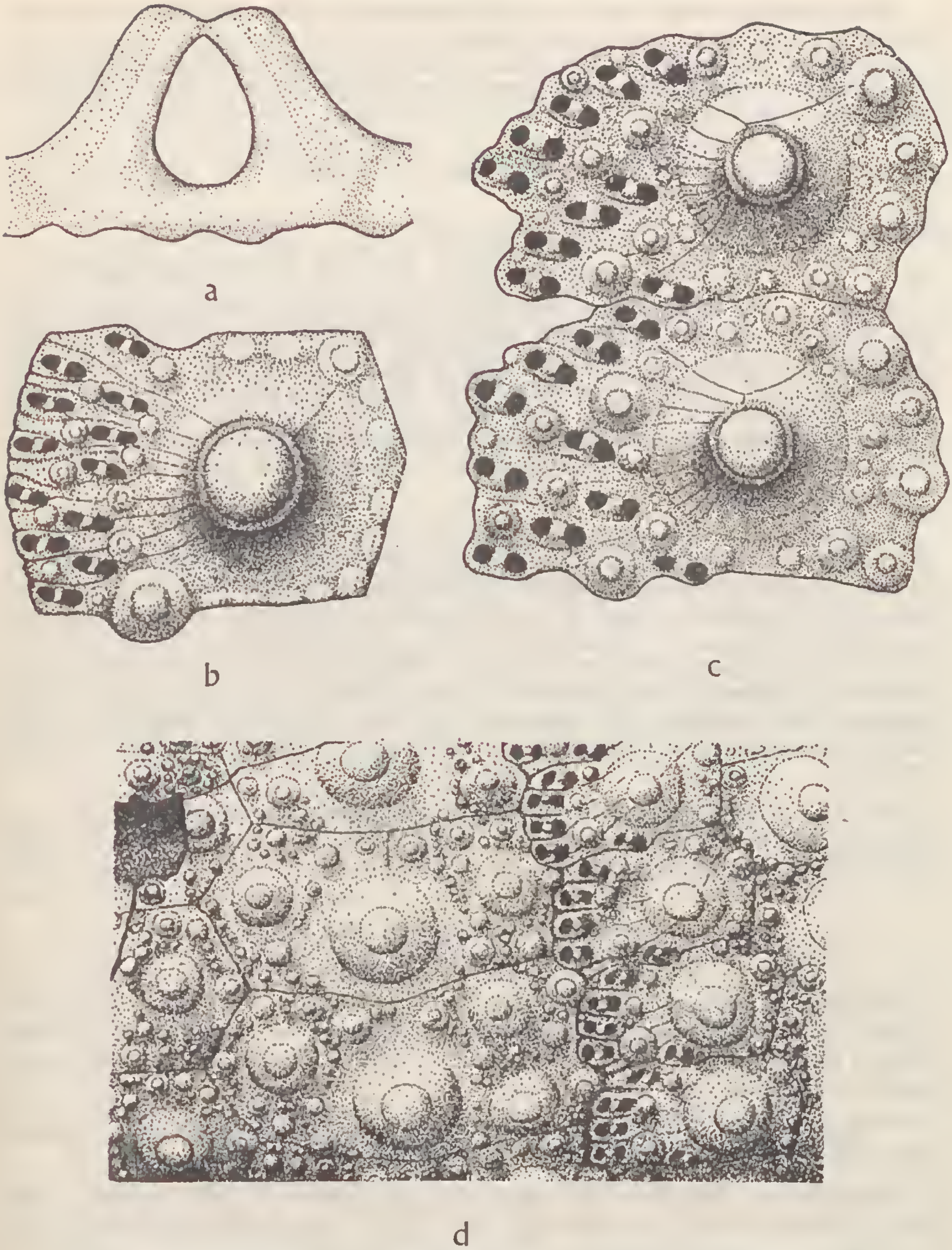


FIG. 4—a, d, *Strongylocentrotus antiquus* sp. nov. a, Auricles of holotype, × 10; d, Ambital plates of holotype, × 6. b, *Zenocentrotus peregrinus*, sp. nov. Ambulacral plate (P 18480), × 6. c, *Heliocidaris ludbrookiae* sp. nov. Ambital ambulacral plates of holotype (AUGD 17015), × 6.

The species is named after Dr N. H. Ludbrook, who very kindly passed on the handsome type specimen for description.

Portion of the lantern is preserved in the hard limestone matrix within the peristome of the holotype, but it proved impossible to excavate without danger of damage to the test.

Genus **Zenocentrotus** A. H. Clark

Zenocentrotus A. H. Clark 1931, p. 5.
Zenocentrotus A. H. Clark, Mortensen 1943b, p. 400.

TYPE SPECIES: *Zenocentrotus kellersi* A. H. Clark, by original designation.

DIAGNOSIS: Moderately large echininids which possess a flattened adoral surface, and an ovate test outline. On the adoral surface the poriferous tracts are widened and petalloid, but above the ambitus the poriferous tracts are narrow and the pore-pairs are arranged in usually distinct double arcs with up to 12 pore-pairs to each compound ambulacral plate. The ambulacra possess only a series of prominent primary tubercles, whereas the interambulacra have enlarged secondary tubercles developed adradially to the primary tubercles. The primary radioles are comparatively stout.

REMARKS: The occurrence of this genus in the Australian Palaeogene is of considerable interest inasmuch as the geological history of the specialized polyporous echinids is greatly extended. Indeed, it is surprising to discover this genus and *Heliocidaris* ranging so far back in time. Together with *Strongylocentrotus antiquus,* and *Echinometra thomsoni* Haime (d'Archiac and Haime 1853, p. 207, Pl. 13, fig. 13 a-b) from probably Eocene rocks in India, they represent the oldest known undoubted members of the Suborder Echinina. Because of their very specialized characters (the doubling of the pore-pair arcs and the petalloid ambulacra of the adoral surface) it seems that even a more ancient origin of the group may be postulated.

DISTRIBUTION: Mortensen (1943b) recognized the two reasonably circumscribed species described by A. H. Clark (1931) from Tonga and Samoa. No fossil occurrences of the genus have been reported previously.

Zenocentrotus peregrinus sp. nov.

(Pl. 28, fig. 3-6, Pl. 29, fig. 6, 9; Fig. 4b)

DIAGNOSIS: A large species of *Zenocentrotus* which has up to 12 pore-pairs arranged in double arcs in each compound ambulacral plate. The vertical series of enlarged secondary tubercles are horizontally alternate, so that the interambulacral plates are geniculate.

TYPE SPECIMEN: The holotype is P 18867, the largest available test fragment, from 'Airey's Inlet', i.e. Point Addis Limestone of Janjukian age.

DESCRIPTION: The test was apparently large (some of the fragments from Batesford suggest a h.d. of 100 mm), and thick. The gill slits are shallow and rounded.

Above the ambitus the ambulacral plates (Fig. 4b) are high, each with a large, high, smooth primary tubercle which fills the interporiferous tract in each column. The pore-pairs are arranged in 2 erect arcs, so that the poriferous tract is only about half the width of the interporiferous tract. Secondary tubercles (sometimes very slightly enlarged at the corners of the plates) and granules occur irregularly through the poriferous tract, and form a circlet around the areoles of the primary tubercles. On the adoral surface the arcs become very low, and the poriferous tracts are widened and petalloid, half way to the peristome reaching almost 5 times the width of the interporiferous tract. The primary ambulacral tubercles decrease markedly in size below the ambitus, but continue to the margin of the peristome as a regular series.

The interambulacra possess closely spaced tubercles of size similar to the corresponding ambulacral primary tubercles. These are arranged usually in 3 alternately placed vertical series in each column. Because of this alternation, they appear to be arrayed in diagonal rather than horizontal and vertical series. The horizontal sutures also run between the tubercles, so the plates are distinctly geniculate. The tubercles of the innermost series are the largest and represent the primary tubercles, for, on the adoral surface where the tubercles are greatly reduced in size, it is this series which can be traced to the borders of the peristome.

Synopsis of Material: Beside the holotype, the species is represented by the following test fragments from the Batesford Limestone:

'Filter Quarry', P 18449; 55; 57; 63; 66; 73; 76; 79; 80.
'Upper Quarry', P 19786.
'Batesford', 4 test fragments *ex* Singleton Collection.

Remarks: A number of rather massive, fragmentary diadematacoid radioles is present in the collection from Batesford (Pl. 29, fig. 7). These correspond well with the size of the large tubercles of this species, and in all probability belong to it. The largest is 40 mm long, but probably they were considerably longer than this. The shafts are cylindrical or flattened and are marked by closely spaced longitudinal grooves. Toward its proximal end the shaft expands slightly to a rounded milled-ring. The base is very short, and is rapidly constricted to a small acetabulum. When worn, the distal portion of the radiole is reduced to a rounded knob.

As a confident assessment of specific differences in the available test fragments is impossible, for the present the smaller, probably less highly ornamented form from Airey's Inlet must be placed with the fragments from the younger horizons at Batesford. However, as the species is at present known and defined, its generic relationships are reasonably clear.

The ambulacra, in the large primary tubercles and the consistent regular doubling of the arcs, are similar to those seen in living species of the genera *Heterocentrotus*, *Cobolocentrotus*, and *Zenocentrotus*. However, in *Heterocentrotus* the interambulacra also possess a vertical series of large primary tubercles in each column, and the huge massive radioles are fully characteristic of the genus. Furthermore, in those species of *Cobolocentrotus* which have this type of ambulacra (subgenus *Podophora*) the interambulacra are much more complexly ornamented by enlarged secondary tubercles, among which the primary tubercles may not be distinguished. The genus also is particularly characterized by the peculiar scale-like radioles.

Thus the species can be placed in *Zenocentrotus* with some degree of assurance, particularly in view of the character of the radioles from Batsford, which, although not fully typical of those of living species of *Zenocentrotus* in their rounded milled rings, are unlike those of either *Heterocentrotus* or *Cobolocentrotus*.

From living species of *Zenocentrotus*, *Z. peregrinus* is distinguished by the geniculate interambulacral plates, and the greater number of pore-pairs in the more erect, double arcs of the adapical ambulacra.

References

(Additional to those listed in previous parts)

BELL, A., 1897. A synopsis of the Crustacea and Echinodermata of the upper Tertiaries. *Rept. Yorks. Phil. Soc.* 1896: 12 p.

GREGORY, J. W., 1891. A catalogue of Pliocene Echinoidea in the Reed Collection. ibid. 1890: 37-42, Pl. 1.

CLARK, A. H., 1931. Echinoderms from the islands of Niuafoou and Nukualofa, Tonga Archipelago. *Proc. U.S. Nat. Mus.* 80 (5): 12 p., Pl. 7.

PHILIP, G. M., 1964. The Tertiary echinoids of south-eastern Australia. II. Cidaridae (2). *Proc. Roy. Soc. Vict.* 77: 433-74, Pl. 58-67.

————, 1965. Classification of echinoids. *Journ. Paleont.* 39: 45-62.

Explanation of Plates

Figures × 1 unless otherwise stated.

PLATE 26

Fig. 1-9—*Murravechinus paucituberculatus* (Gregory). (1) Adapical, (2) Lateral, (3) Adoral views of P 17955; (4) Adapical, (5) Lateral, (6) Adoral views of a small specimen P 17956; (7) Adapical view of P 17955, × 2; (8) Superambital, (9) Subambital view of P 17955, × 5. Specimens from 'Morgan', Batesfordian or Balcombian.

Fig. 10-15—*Salenidia tertiaria* (Tate). (10) Lateral view of lectotype BM GSL 14084a (British Museum photograph); (11) Adapical, (12) Lateral, (13) Adoral views of lectotype of *Salenia globosa* Tate AUGD T 275B; (14) Apical system of AUGD T 1727A, showing pierced madreporite, × 5; (15) Ambital view of AUGD 17013, × 5. Specimens from the Upper Eocene Tortachilla Limestone.

PLATE 27

Fig. 1-4—*Heliocidaris ludbrookae* sp. nov. (1) Adapical, (2) Lateral views of Holotype AUGD 17015, 'Mannum', Longfordian; (3) Test fragments P 18472, P 18469; (4) Test fragments P 18450, P 18462, 'Batesford', Longfordian or Batesfordian.

Fig. 5—*Heliocidaris ludbrookae* sp. nov. (?) Radioles P 19637-40, 'Middle Quarry, Batesford', Longfordian or Batesfordian.

PLATE 28

Fig. 1-2—*Heliocidaris ludbrookae* sp. nov. (1) Adoral, (2) Superambital view of holotype AUGD 17015, × 2.

Fig. 3-6—*Zenocentrotus peregrinus* sp. nov. (3) Ambulacral plates P 19786, 'Upper Quarry, Batesford', Longfordian or Batesfordian, × 2; (4) Ambulacral plates P 18480, 'Filter Quarry, Batesford', Longfordian or Batesfordian, × 2; (5) Adoral, (6) Lateral views of holotype P 18867, 'Aireys Inlet', Janjukian, × 2.

PLATE 29

Fig. 1-3—*Strongylocentrotus antiquus* sp. nov. (1) Adapical, (2) Lateral, (3) Adoral views of holotype AUGD 17014, 'Glenforslan', Longfordian.

Fig. 4-5—Toxopneustid gen. et. sp. indet. (4) Test fragment P 18868, 'Aireys Inlet', Janjukian, × 2; (5) Test fragment P 18865, same locality, × 2.

Fig. 6, 9—*Zenocentrotus peregrinus* sp. nov. (6) Broken interambulacral zone P 18473, 'Filter Quarry, Batesford', Longfordian or Batesfordian, × 2; (9) Broken interambulacral zone with attached poriferous tract P 18476, showing geniculation of interambulacral plates, same locality, × 2.

Fig. 7—*Zenocentrotus peregrinus* sp. nov. (?) Radioles P 19652, 'Batesford', Longfordian or Batesfordian, × 2.

Fig. 8—*Strongylocentrotus* sp. Test fragments P 18459, P 18468, 'Filter Quarry, Batesford', Longfordian or Batesfordian, × 2.


1


2

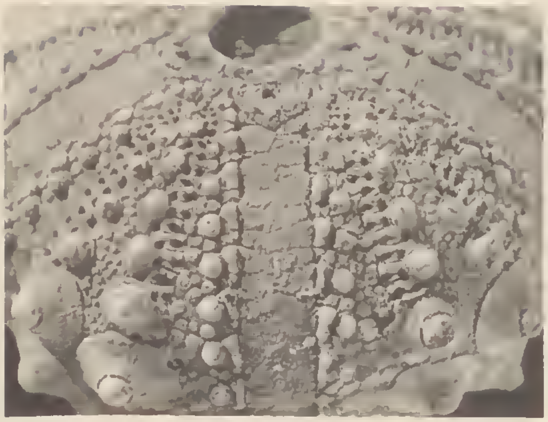

3

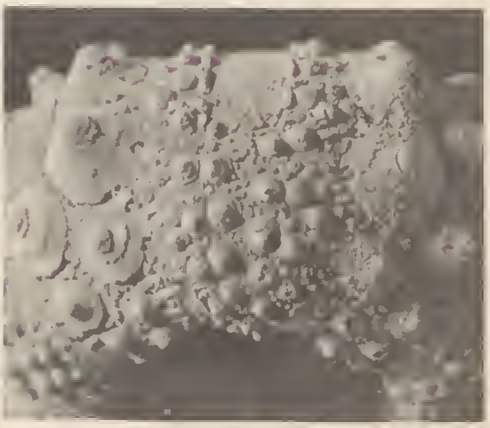

7


4


5

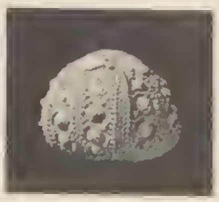

6


8

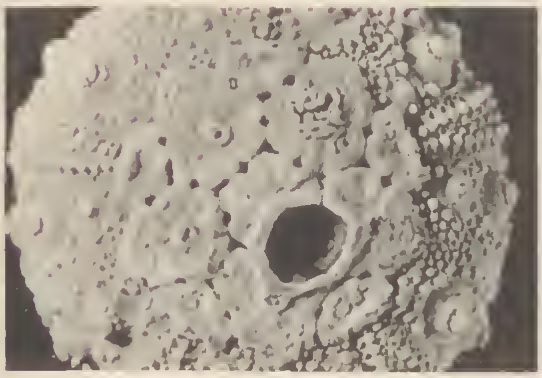

9

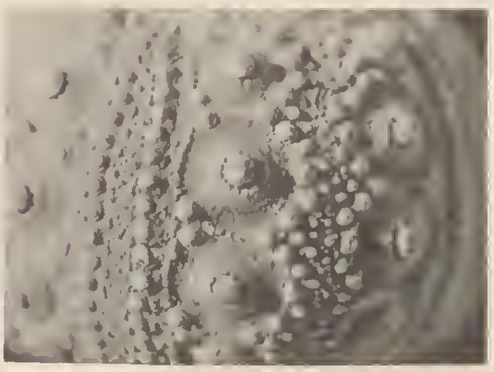

10


11


12


13


14


15

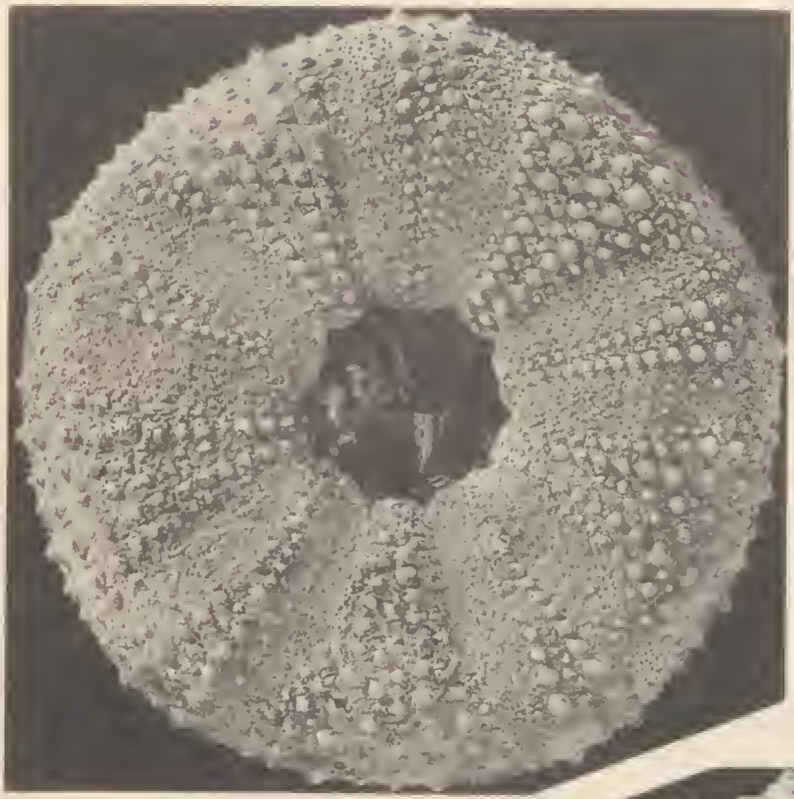

1


3


4


2


5

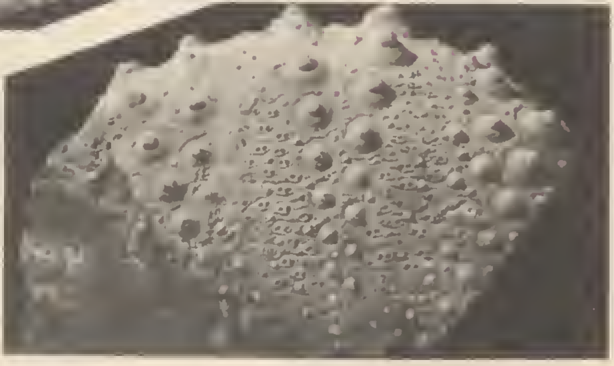


1

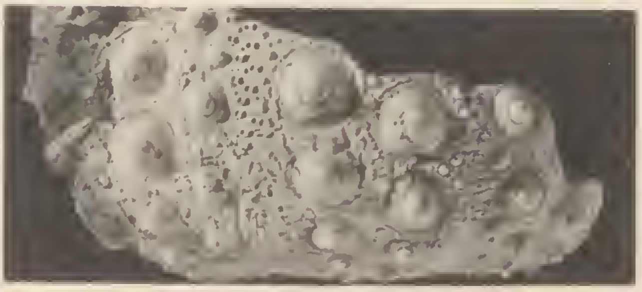
3

4

2



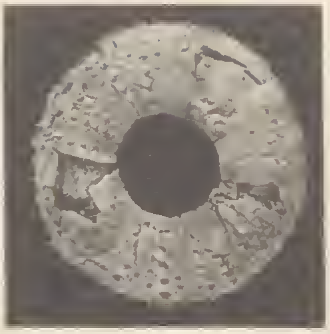
5



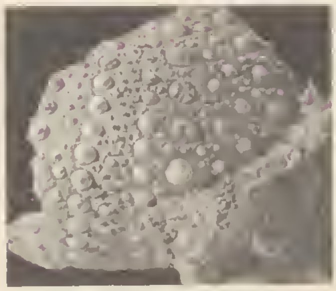
6

1

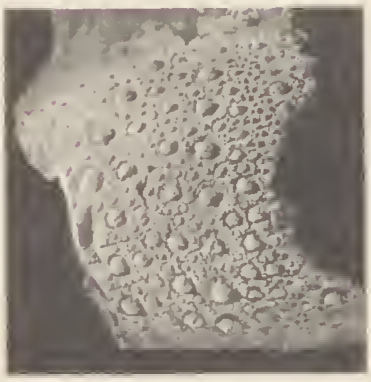
2



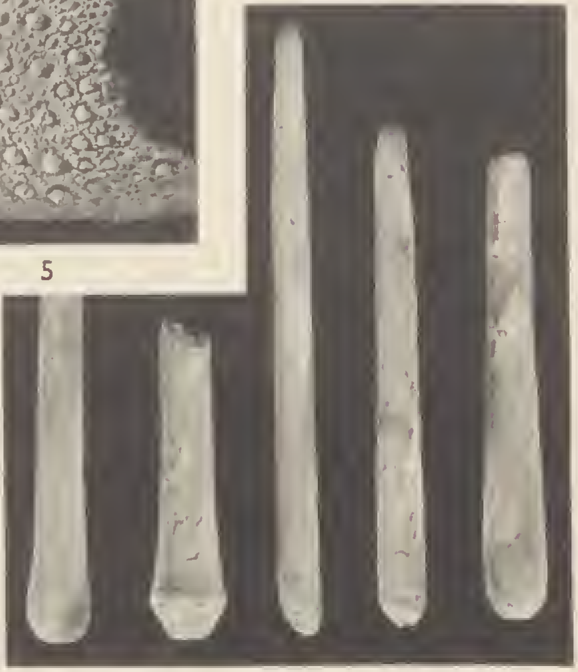
3



4

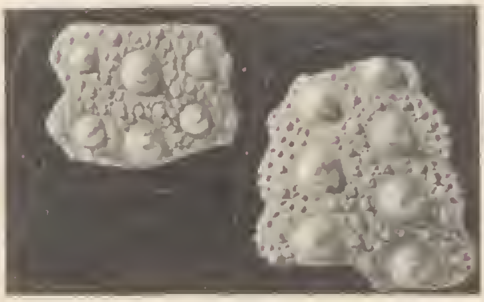


5



7

6



8

9

14

FUSED LATERITE IN A CALDERA NEAR SKIPTON, WESTERN VICTORIA

By P. L. C. Grubb

CSIRO Mineragraphic Investigations, Melbourne

Abstract

Two small orange-coloured inclusions found in a highly porous cinder ash flow on the N. flank of a small caldera in W. Victoria are considered to be partially fused laterites.* Although essentially glassy in nature, some detrital quartz, zircon, sodic plagioclase, plus metakaolin can be recognized, yet the sole high-temperature mineral present comprises a trace of cristobalite. These facts, together with the conspicuously dehydrated nature of the inclusions, suggest their submission to high temperatures, though not exceeding 950°C.

* The term 'laterite' is adopted for the material described on account of its distinctive mineralogy and high proportion of hard ferruginous pisolites.

Introduction

In a small but well-preserved volcanic caldera just N. of Skipton in W. Victoria, two 6-8 in. orange-coloured bomb inclusions were found exposed in the semi-consolidated coarse steeply-dipping ash flow forming part of the caldera's N. flank. These inclusions possessed a conspicuous hackly fracture with a semi-vitreous lustre on fresh surfaces while, in addition, several small ⅛-¼ in. hematite pisolites are recognizable.

Microscopic Data

An examination of thin sections and polished surfaces of the fused laterites has shown that these consist essentially of an isotropic glass with an abundance of finely disseminated hematite particles, whereas the remaining components include detrital quartz grains plus accessory zircon, magnetite, sodic plagioclase, and pyrite. Through partial recrystallization, however, the hematite pisolites possess a poor zonal structure showing more coarsely crystalline margins enclosing cores of earthy texture.

X-ray Diffraction

Owing to the predominantly glassy nature of the fused laterites, background counts for all wave-lengths were characteristically high, thus effectively reducing the maximum resolution power of X-ray powder diffraction traces for these samples. Nevertheless, strong diffraction peaks could be indexed for both quartz and hematite plus additional traces of metakaolin and cristobalite.

Estimations of the total quartz content obtained by the phosphoric acid method indicated a value of 29·5 per cent. Hence, as the total silica content is 65·8 per cent (Table 1), this may be taken as still further evidence of the predominantly glassy nature of these laterites. An approximate estimate of their modal composition is shown in Table 2.

Chemical Analyses

Chemical analyses reveal little similarity between the baked Skipton laterite and that of a typical laterite derived from the Newer Basalts in the area (CSIRO Min. Rept No. 869). The most conspicuous feature of the former is the extremely low combined-water content, which probably arises from the intense baking in the

TABLE 1

Chemical analysis of a baked laterite bomb from the Skipton caldera, W. Victoria

	% by wt
SiO_2	65·80
Al_2O_3	18·88
Fe_2O_3	10·24
TiO_2	trace
H_2O (+105°C)	1·87
H_2O (−105°C)	3·76
Total	100·55
% free silica as quartz	29·50%

TABLE 2

Estimated mineralogical composition of Skipton baked laterite, W. Victoria

	% by wt
Quartz	29·50
Hematite	10·60
Metakaolinite	13·70
Glass and cristobalite	46·00
Total	99·80

caldera. This apparently resulted in the conversion of goethite to hematite, some quartz to cristobalite, and partial vitrification of quartz, felspar, and kaolin. Thus, the changes involved were very similar to those encountered in comparable ceramic products after firing (Williamson 1949).

Conclusions

Local occurrences of fused clays, laterites, and shales are not uncommon in Victoria; these, for the most part, being associated with local burn-outs in coal seams or even in hollowed tree trunks where draught conditions were at an optimum. The mineral assemblages produced under these conditions are generally of an extremely high-temperature nature and often comparable with those encountered in certain blast furnace linings (CSIRO Min. Rept No. 864) while, in addition, they are also often distinctly slaggy in appearance.

As these characteristics are almost completely lacking in the fused Skipton laterites, an attempt was made to estimate their approximate thermal history by heating two related lateritic products for set periods at varying temperatures in a muffle furnace. The products of each successive run were examined microscopically and by X-ray diffraction, the results being listed in Table 3.

The most significant features noted in these are:

(1) no vitrification was observed below 800°C;

(2) cristobalite was detected only at about 1000°C (similar temperatures of formation being also commonly observed in ceramic products);

(3) although the usual phases formed at temperatures between 800°C and 1000°C, both in these runs and in those carried out by Glass (1954) and by Bradley and Grim (1951), are mullite and corundum, neither of these constituents were detected in the baked Skipton laterites.

In conclusion, therefore, despite the absence of any detectable corundum or mullite, it seems evident that the two laterite bombs were subjected to high tempera-

TABLE 3

Mineralogical changes observed in lateritic products at varying temperatures

Starting materials	Temperature °C	Time hr	Mineral phases identified	Remarks
Laterite (mottled) from Hamilton, Victoria	600	2½	χ—Al_2O_3 kaolinite quartz	Moderate darkening of laterite to a deep brown colour
	800	4	χ—Al_2O_3 hematite quartz	Incipient fusion with occasional thin glassy selvages
	1000	2	mullite cristobalite hematite	Predominantly glassy indicating total fusion
Unconsolidated 'earthy' bauxite from Jarrahdale, Western Australia	600	1¾	χ—Al_2O_3 quartz	Little change evident
	800	2	χ—Al_2O_3 corundum quartz	Pale buff friable product, little or no glassy fusion evident, well formed quartz crystals conspicuous
	1000	1	corundum quartz trace of cristobalite	Pale buff friable product, no glassy fusion evident, secondary growth of quartz crystals very conspicuous

tures though not exceeding 950°C. They were intensely dehydrated, and even the small percentage of water present may be partly due to subsequent 'moisture expansion', a feature commonly encountered in fired ceramic products after cooling (Williamson 1949).

Acknowledgements

The writer is grateful to Mr A. J. Gaskin and Dr G. Baker for their useful comments and suggestions to this paper.

Selected References

BRADLEY, W. F., and GRIM, R. E., 1951. High temperature thermal effects of clay and related materials. *Amer. Min.* 36: 182-201.

BRINDLEY, G. W., and CHOE, J. O., 1961. Reaction series gibbsite-alumina-K-alumina. ibid. 46: 771-785.

CSIRO MINERAGRAPHIC INVESTIGATIONS, Melbourne, 1963. Rept No. 864 and 869.

GLASS, H. D., 1954. High temperature phases from kaolinite and halloysite. *Amer. Min.* 39: 193-207.

HELLER, L., 1962. The thermal transformation of pyrophyllite to mullite. ibid. 47: 156-157.

TALVITE, M. A., 1951. Determination of quartz in presence of silicates using phosphoric acid. *Analytical Chemistry* 23: 623-624.

WILLIAMSON, W. O., 1949. Ceramic products; their geological interest and analogies. *Am. J. Sci.* 247: 715-749.

15

A REVISION OF THE AUSTRALIAN DEVONIAN CORALS PREVIOUSLY REFERRED TO *MICTOPHYLLUM*

By A. E. H. PEDDER

Department of Geology, University of New England, Armidale

Abstract

The earliest known occurrences of *Mictophyllum* are in beds of Givetian age in the Urals and Hunan. The genus was considerably more prolific in Frasnian time and is represented by about a dozen described species from New York, Nevada, W. Canada, the Russian Platform and Hunan.

Mictophyllum has been reported on several occasions from SE. Australia in beds now known to range in age from possible late Gedinnian to Emsian. However, a reinvestigation of the corals upon which these reports are based indicates not only that none is truly *Mictophyllum*, but also that all belong to new genera.

As a result of the present revision, the taxonomy and distribution of these corals become:

Family DISPHYLLIDAE

Chalcidophyllum campanense gen. et sp. nov., Siegenian, Waratah Bay, Vict.
C. campanense var. *nanum* nov., Siegenian, Waratah Bay, Vict.
C. discorde sp. nov., Siegenian, Waratah Bay, Vict.
Disphyllum angulare and '*Campophyllum*' *recessum* from Emsian beds at Buchan, Vict., and Siegenian beds on Murrumbidgee R., N.S.W., are also referred to the new genus.

Family BETHANYPHYLLIDAE

Strathmoelasma amplum gen. et sp. nov., late Emsian or early Eifelian, Sulcor, N.S.W.

Family STERICTOPHYLLIDAE nov.

Sterictophyllum cresswelli (Chapman), Siegenian, Lilydale, Vict.
S. vallatum nom. nov., late Gedinnian or Siegenian, Tyers R., Vict.
Dohmophyllum pridianum from late Gedinnian or Siegenian beds on Tyers R., Vict., is also referred to *Sterictophyllum*.
Loomberaphyllum pustulosum gen. et. sp. nov., late Emsian or early Eifelian, Loomberah and Sulcor, N.S.W.
L. impensum nom. nov., late Gedinnian or Siegenian, Tyers R., Vict.

Family CYATHOPHYLLIDAE

Cavanophyllum trochoides (Hill), Siegenian, Murrumbidgee and Goodradigbee R., N.S.W.

Introduction

The genus *Mictophyllum* was proposed by Lang and Smith (1939, p. 155) for a Frasnian coral from the NW. Territories of Canada. On several occasions subsequently the genus has been identified in both Victoria and New South Wales.

In Victoria, the reported occurrences are in the Lilydale Limestone at Lilydale (Hill 1939a, p. 246), the Bell Point Limestone at Waratah Bay (Hill 1954b, p. 109, 110), and in a limestone within the Coopers Creek Formation on Tyers R. (Philip 1962, p. 180). Hill believed the Lilydale Limestone to be 'older than Upper Devonian' and the Bell Point Limestone to be possibly Couvinian. Philip, however, regarded his specimen from Tyers R. as being 'early Lower Devonian'.

In New South Wales, corals referred to *Mictophyllum* have been described from the Cavan Bluff Limestone near Taemas (Hill 1940, p. 265) and the Sulcor Limestone near Attunga (Hill 1942b, p. 144). It was thought that the first is 'somewhere near the base of the Couvinian or perhaps the top of the Coblenzian' and that the second is early Couvinian.

During the quarter of a century that has elapsed since the first of these reports of the genus in Australia, much new information concerning the composition and distribution of Devonian coral faunas in various parts of the world has become available. Of particular interest from the Australian point of view has been the publication of works describing faunas in the Urals, the Kuznets Basin, and Asia. Also in recent years, correlations of some of the best-known Australian Devonian successions have been modified (Philip 1960; Philip and Pedder 1964). It is now clear that the temporal interval between the overseas occurrences of *Mictophyllum* and those of the Australian species referred to the genus, is greater than was previously realized.

Field-work recently undertaken by G. M. Philip and the writer, as a step towards elucidation of the Devonian correlation problems in SE. Australia, has provided opportunities for acquiring additional specimens of most of the Australian species. The present work is in two parts. Firstly, *Mictophyllum* and other superficially similar genera are reviewed and secondly, the systematics of the Australian species are revised.

Costs incurred by field-work have been met almost entirely by the University of New England's Research Grant No. 120. The author has also been aided by E. D. Gill of the National Museum of Victoria, who arranged for the loan of specimens to supplement the available material from Lilydale; by D. L. Strusz of the University College of Townsville, who permitted access to his unpublished PhD thesis; and by A. A. Baker of the Geology Department, University of Melbourne, who made several type specimens available to the author. The final acknowledgement is to G. M. Philip, whose conodont studies have contributed considerably in the determination of the ages of the Australian coral faunas.

Systematic Descriptions

Fossil collections are symbolized as follows:

AM—Australian Museum, Sydney
GSV—Geological Survey of Victoria, Melbourne
NMV—National Museum of Victoria, Melbourne
UM—University of Melbourne, Melbourne
UNE—University of New England, Armidale
UQ—University of Queensland, Brisbane
US—University of Sydney, Sydney.

Family DISPHYLLIDAE Hill

Genus **Mictophyllum** Lang and Smith

1939 *Mictophyllum* Lang and Smith, p. 155.
1958 *Disphyllum* (*Sinodisphyllum*) Sun, p. 11, 12.

TYPE SPECIES (of *Mictophyllum*): *M. nobile* Lang and Smith 1939, p. 155, Pl. 4, fig. 1. Beds now (Belyea and McLaren 1962) referred to the late Frasnian Redknife Formation, Redknife R., NW.T., Canada.

TYPE SPECIES (of *Sinodisphyllum*): *S. variabile* Sun 1958, p. 12, Pl. 4, fig. 1, 2; Pl. 5, fig. 1; Pl. 6, fig. 1. Lungkouchung Formation (Frasnian), Hsianghsiang, Hunan, China.

REMARKS: The type species of *Sinodisphyllum* is greatly more representative of the genus than is the type species of *Mictophyllum*. *M. variabile* is a medium sized ceratoid to subcylindrical coral with slightly dilated and radially arranged septa. Development of the minor septa is variable and a herringbone dissepimentarium may be present. It is said that the trabeculae are disphyllid. The dissepiments are numerous, relatively small, and commonly inosculate. The tabulae may be short or long in longitudinal section and peripherally may be down-turned, upturned or simply abut against another tabula or dissepiment. There is a trend in the genus towards suppression of the minor septa and development of a herringbone dissepimentarium. *M. nobile* is a late species very near the end of this trend and, consequently, is almost devoid of minor septa.

In the past, species of the genus have been referred to a number of genera, including *Aulacophyllum, Campophyllum, Cyathophyllum,* and *Tabulophyllum.*

Aulacophyllum is distinct for several reasons, the most obvious being that the septa are radially arranged in *Mictophyllum*, whereas they are pinnate about the cardinal septum in *Aulacophyllum.* The dilation of the septa, if present is also different, and in *Aulacophyllum* the dissepiments are not normally inosculating.

Birenheide (1963, p. 376) has recently revised *C. dianthus*, the type species of *Cyathophyllum*, and has shown it to be a compound coral in which the septa are zigzagly carinate and tend to become diffuse peripherally.

Cyathophyllum flexuosum Goldfuss, the type species of *Campophyllum*, was probably wrongly located in the original description and is believed to be a Carboniferous species. The type material has never been adequately described and, according to Mensink (in Semenoff-Tian-Chansky 1962, p. 298), was probably destroyed in Berlin during World War II. With such circumstances the genus is obviously unusable but, in any case, it is generally held to be close to either *Palaeosmilia* or *Caninia* (Lang, Smith, and Thomas 1940, p. 30).

Tabulophyllum is a variable genus and a few of its species approach *Mictophyllum*. However, the similarity is superficial as *Tabulophyllum* has a very different skeletal structure (Pedder 1965, Fig. 2). Most species of *Tabulophyllum* possess lonsdaleoid dissepiments and therefore do not simulate *Mictophyllum.*

The known distribution of *Mictophyllum* is summarized thus:

Givetian, Urals

Campophyllum litvinovitschae Soshkina 1952, p. 88, 89, Pl. 23, fig. 87 (the earlier, 1949 reference is not available to the present author).

Givetian, Asia

Campophyllum lindstroemi Ma 1956, Pl. 32, fig. 1-4; Pl. 33, fig. 1, 2. Hsianghsiangsien, Hunan.

Frasnian, Asia

Tabulophyllum curvatum Sun 1958, p. 10, 11, Pl. 1, fig. 4, 5. Hsianghsiang, Hunan.
Disphyllum cylindricum Sun in Wang et al. 1957, p. 32, Pl. 12, fig. 5, 6, 9; Sun 1958 (as *Sinodisphyllum*), p. 10, Pl. 1, fig. 3. Hsianghsiang, Hunan.
Ptychophyllum giganteum Sun in Wang et al. 1957, p. 35, Pl. 14, fig. 4, 5; Sun 1958 (as *Tabulophyllum*), p. 11, Pl. 2, fig. 1; Pl. 3, fig. 1, 2. Hsianghsiang, Hunan.
Sinodisphyllum simplex Sun 1958, p. 12, 13, Pl. 5, fig. 2, 3; Pl. 6, fig. 2. Hsianghsiang, Hunan.
Sinodisphyllum variable Sun 1958, p. 12, Pl. 4, fig. 1, 2; Pl. 5, fig. 1; Pl. 6, fig. 1. Hsianghsiang, Hunan.

Frasnian, North America

Mictophyllum modicum Smith 1945, p. 32, 33, Pl. 5, fig. 1-6; Pl. 7, fig. 8; McLaren et al. 1961, Pl. 5, fig. 3-5. Upper Mackenzie Valley and Hay River.
Mictophyllum near *modicum* Smith 1945, p. 33, Pl. 5, fig. 7, 8. Upper Mackenzie Valley.
Mictophyllum multiseptatum Smith 1945, p. 33, 34, Pl. 5, fig. 9. Upper Mackenzie Valley.
Mictophyllum nobile Lang and Smith 1939, p. 155, Pl. 4, fig. 1; Smith 1945, p. 30, 31, Pl. 4, fig. 1. Upper Mackenzie Valley.
Mictophylllum semidilatum Smith 1945, p. 31, 32, Pl. 4, fig. 2, 3. Upper Mackenzie Valley.
Cyathophyllum sp. c, Merriam 1940, Pl. 14, fig. 3. Devils Gate, Nevada.
Mictophyllum orientale Stumm 1960, p. 162, Pl. 30, fig. 1-3. Tioga County, New York.

Frasnian, Europe

Aulacophyllum ornatum Soshkina 1952, p. 68, 69, Pl. 3, fig. 13; 1954, p. 27-30, fig. 3, 4, Pl. 2, fig. 1-5; Pl. 3, fig. 1, 2. Russian Platform.

Genus **Chalcidophyllum** nov.

NAME DERIVATION: Gk. χαλκίς = herring-like fish, and φύλλον = leaf.

TYPE SPECIES: *Chalcidophyllum campanense* sp. nov., see below.

DIAGNOSIS: Corallum weakly compound; corallites trochoid to cylindrical. Epitheca deeply invaginated at the septa giving rise to prominent septal grooves. Septa smooth, thin, radially arranged, typically highly differentiated into two orders and in some cases the minor septa are almost completely suppressed. Dissepiments numerous in large species, relatively less numerous in small species, inosculating and in some species forming a herringbone dissepimentarium. At the periphery they are small, but become larger and more elongate towards the tabularium. Tabulae broad and typically depressed axially.

ADDITIONAL SPECIES ASSIGNED: *Disphyllum angulare* Hill 1950, p. 141, 142, Pl. 6, fig. 10. Murrindal Limestone (Emsian) (Philip and Pedder 1964), Buchan, Vict.

Chalcidophyllum discorde sp. nov., see below.

'Campophyllum' recessum Hill 1940, p. 254-256, Pl. 9, fig. 7. Currajong Limestone (Siegenian) (Philip and Pedder 1964); Murrumbidgee R., N.S.W.

REMARKS: The species for which *Chalcidophyllum* is being erected have previously been referred to either *Campophyllum, Breviphyllum, Disphyllum,* or *Mictophyllum*.

Since *Campophyllum* had been shown to be an unusable Carboniferous genus, Stumm (1949, p. 25) erected *Breviphyllum* for the Devonian species that had been placed in it. However, as used, *Campophyllum* was polyphyletic, some species such as *C. yunnanense* Reed (1927, p. 10, Pl. 1, fig. 6-11) are probably streptelasmatids, whereas others (Wedekind 1925, Pl. 16, fig. 97-99; Yoh 1937, p. 61, Pl. 7, fig. 5, 6) are disphyllids. If species such as *Breviphyllum mons* Clauss (1956, p. 20, Fig. 4), which is probably a polycoeliid, are included, the genus becomes even more polyphyletic. *Amplexus lonense* Stumm (1937, p. 428, Pl. 53, fig. 4; Pl. 54, fig. 4), the type species of *Breviphyllum,* is an Emsian (House 1962, p. 252, 253; Johnson 1962) coral from Nevada. It is trochoid and has short peripherally dilated septa, flat complete tabulae and a few large irregular dissepiments. Species of *Chalcidophyllum* are distinguished from it by their growth form, long, peripherally thin septa, narrower, axially sagging tabularium, and by their smaller, more numerous dissepiments.

Mictophyllum resembles *Chalcidophyllum* but is distinguished by its growth form and by the relationship of its septa to the wall, which is not invaginated to form prominent septal grooves. Although both genera appear to have evolved from the disphyllinid stock, they probably did so independently. *Chalcidophyllum* is confined to the Siegenian and early Emsian of Australia and is evidently a small endemic genus. *Mictophyllum*, on the other hand, is apparently a widespread Givetian and Frasnian genus.

Chalcidophyllum campanense sp. nov.

(Pl. 30, fig. 2, 6-12; Pl. 34, fig. 2)

1954b *Mictophyllum cresswelli* (Chapman) Hill, p. 109, Pl. 7, fig. 8.
non 1925 *Cyathophyllum cresswelli* Chapman, p. 111, 112, Pl. 13, fig. 11-14.

NAME DERIVATION: L. *campana* = bell, hence *campanensis* from Bell Point.

MATERIAL: Holotype, UNE F8786. Paratypes 1-5, UNE F8787-8791. All were obtained from the Bell Point Limestone (Siegenian), immediately N. of Bell Point, Waratah Bay, Vict. The specimen described by Hill (1954b) is UQ F17134 and is an approximate topotype.

Diagnosis: Corallum weakly compound; corallites trochoid to subcylindrical and up to 35 mm in diameter. Septa radially arranged, highly differentiated into two orders, numbering from about 30 × 2 to 37 × 2 in adult corallites. Dissepiments numerous, forming a wide herringbone dissepimentarium. Tabulae broad, but incomplete, sloping so that the tabularium is depressed axially.

Description: At the type locality the corallites are close and abundant, but only rarely are connections seen between them. In early stages they are trochoid to ceratoid, but later may become subcylindrical; their adult diameter is from about 30 to 35 mm. The exterior bears deep septal grooves as well as fine horizontal growth lines and coarser rugae. The only calice seen is subconical and about 12 mm deep.

The wall is confluent with the septa and consequently is only about one-half the width of the septa at their periphery.

The septa are radially arranged, smooth and highly differentiated into two orders. Septal counts are as follows (measurements in mm):

Specimen	Mean diameter	No. of septa
UNE F8787	19	36 × 2
UNE F8790	20	33 × 2
UNE F8788	24	31 × 2
UNE F8791	30	30 × 2
UNE F8788	32	33 × 2
UNE F8787	33	37 × 2
UNE F8788	35	31 × 2

For a short but variable distance inside the wall, the septa are thickened about a median dark lamella, which is invaginated axial plate (Flower 1961, p. 28). The major septa may extend to the axis or terminate up to 8 mm from it; in places (UNE F8788) they are discontinuous. The minor septa are normally confined to the periphery of the dissepimentarium, abnormally they are well developed, and in one part of the holotype are 9 mm long. The trabeculae are directed upwards and inwards at about 45°.

The dissepiments, which are generally small relative to the size of the coral, are arranged to form a wide herringbone dissepimentarium; in transverse section they tend to be globular or even rhomboid towards the periphery, but become more elongate towards the tabularium.

The tabulae are broad but not complete. Marginally they may abut against a dissepiment or grade into long steep tabellae. In fully orientated longitudinal sections there is a marked axial sag in the tabularium and the division between the tabularium and dissepimentarium is distinct.

Comparison: The species is the largest known of the genus and is unlikely to be confused with others.

Chalcidophyllum campanense var. **nanum** nov.

(Pl. 30, fig. 1, 3-5)

? 1954b *Mictophyllum* sp., Hill, p. 109, 110, Pl. 7, fig. 10.
? 1956 *Campophyllum isactis* (Frech) Ma (*pars*), p. 46. Waratah Bay specimens only.
non 1886 *Cyathophyllum isactis* Frech, p. 75, 76, Pl. 1 (13), fig. 7; Pl. 2 (14), fig. 13-18.

Name Derivation: L. *nanus* = dwarf.

MATERIAL: Paratypes 6-8, UNE F8792-8794. All from the Bell Point Limestone (Siegenian), immediately N. of Bell Point, Waratah Bay, Vict. The specimen figured by Hill (1954b) is UM 2023 and comes from a limestone (probably Siegenian) SE. of Hughes Jetty, Waratah Bay, Vict.

DIAGNOSIS: A variety of *Chalcidophyllum campanense* distinguished by its narrower (up to 20 mm in diameter) and more cylindrical corallites and by its slightly fewer (up to 30 × 2) septa.

COMPARISONS: The dimensions and septal counts of this variety are the same as those of *C. angulare*. In *C. campanense* var. *nanum*, however, the dissepimentarium is more uniform and the tabularium narrower.

Chalcidophyllum discorde sp. nov.

(Pl. 30, fig. 14, 15; Pl. 34, fig. 1)

? 1940 Gen. et sp. indet., Hill, Pl. 9, fig. 9.
1954b *Mictophyllum cresswelli* (Chapman) var. *cylindricum* Hill, p. 109, Pl. 7, fig. 9.
non 1925 *Cyathophyllum cresswelli* Chapman, p. 111, 112, Pl. 13, fig. 11-14.

NAME DERIVATION: L. *discors* = different.

MATERIAL: Holotype UNE F8795. Bell Point Limestone (Siegenian), immediately N. of Bell Point, Waratah Bay, Vict. Paratype (Holotype of var. *cylindricum*), UM P4. Bell Point Limestone, Bell Point, Waratah Bay, Vict.

The specimen figured by Hill (1940) is AM F9909; it was collected at Cavan, Murrumbidgee R., N.S.W. and is likely to have been obtained from Siegenian beds.

DIAGNOSIS: Corallum probably weakly compound; corallites ceratoid at first becoming cylindrical later. At maturity the diameter of the corallite is about 20 mm and there are about 29 × 2 septa. Dissepiments numerous but variable. The tabularium consists of an outer zone of inosculating tabellae and an inner region of generally flat tabulae.

DESCRIPTION: The corallite constituting the holotype is surrounded by several others and it is probable that the corallum is weakly compound. Individual corallites are ceratoid to subcylindrical with a maximum diameter of at least 22 mm. One longitudinal section shows several constrictions of the corallite; otherwise little is known of the exterior.

The wall is confluent with the peripheral ends of the septa and bears prominent septal grooves resulting from invaginations of the axial plate. Wall thickness at maturity is about 0·3 or 0·4 mm.

Septa are radial in arrangement, smooth, and well differentiated into two orders; they number from 27 × 2 to 31 × 2 in adult stages and are typically a little dilated in the dissepimentarium. The major septa may extend almost to the axis, but more commonly are withdrawn 2 or 3 mm from it. In the larger transverse section of the holotype they are again dilated in a concentric zone within the tabularium. This is likely to be due to an impending rejuvenescense. The minor septa are variably developed; normally they are from one-quarter to one-half the length of the major septa; in places they are discontinuous.

The dissepimentarium at the adult stage is from 3 to 5 mm wide and consists of numerous dissepiments of discrepant size and shape. There is a tendency for the dissepiments to inosculte and in places they are invested by thin sclerenchyme, which is confluent with the septa.

Two regions are discernible in the tabularium. The outer consists of cystose, typically inosculating tabellae, which may be either convex upwards, or be so inclined as to grade into dissepiments. The inner region consists of tabulae, which may be flat, rather than sagging as in other species of the genus.

Remarks: The provisions of the International Code of Zoological Nomenclature do not apply to infrasubspecific taxa (Articles 1 and 45c). Although it would be possible to elevate Hill's varietal name *cylindricum* to species rank (Article 10b), it is not completely beyond doubt that the holotype of the variety, in fact, is conspecific with the holotype of the new species. For this reason, and also because the holotype is a ceratoid coral, the name *cylindricum* is abandoned.

Family Bethanyphyllidae Stumm emended

Stumm (1949, p. 17) believed that the Acanthophyllidae evolved from the Zaphrentidae by gradual development of dissepiments and loss of the cardinal fossula. Several genera, both with and without yard-arm carinae, were considered to be intermediate between the zaphrentids and the acanthophyllids and were placed in a new family, the Bethanyphyllidae. It is now generally agreed that the acanthophyllids are not closely related to the other families and *Bethanyphyllum* is usually placed in the Zaphrentidae. In her last work, Soshkina (in Orlov 1962) became the only recent author to recognize the Benthanyphyllidae. However, her interpretation of the family was excessively broad and several of the 14 genera included in it are unrelated.

As presently emended, the family accommodates *Bethanyphyllum, Ceratophyllum, Moravophyllum, Tortophyllum,* and the new genus *Stathmoelasma.* In these genera the corallum is simple, the septa are smooth, or only weakly carinate and the cardinal septum is shorter than the neighbouring major septa. The absence of yard-arm carinae distinguishes the Bethanyphyllidae from the Zaphrentidae. It is possible that the family was derived from the Halliidae.

Genus **Stathmoelasma** nov.

Name Derivation: Gk σταθμός = pillar, and ἔλασμα = plate.

Type Species: *Stathmoelasma amplum* sp. nov., see below.

Diagnosis: Corallum large, ceratoid to cylindrical. Epitheca thin. Septa radially arranged, smooth, thin, numerous and well differentiated into two orders; cardinal septum shorter than neighbouring major septa. Dissepiments small, forming a broad dissepimentarium. Tabularium with peripheral tabellae and broad, domed or peripherally downturned tabulae.

Species Requiring Further Study: *Cyathophyllum cailliaudi* Barrois 1889, p. 47-49, Pl. 2, fig. 2. Calcaire d'Erbray (Emsian, according to Péneau 1962), France.

Cyathophyllum? *lonense* Stumm 1937, p. 435, Pl. 55, fig. 3. Nevada Limestone (Emsian part), Nevada.

Comparisons: Several American species are now referred to *Bethanyphyllum.* Early forms from the Emsian of Nevada and Ohio (Stumm 1937, Pl. 54, fig. 9; Pl. 55, fig. 1, 2; Stewart 1938, Pl. 6, fig. 1, 2) have an obvious cardinal fossula and broad, somewhat sagging tabulae. Later forms from the Givetian of Michigan (Stumm 1963, Pl. 5, fig. 3, 4; Pl. 7, fig. 5-8) have a less obvious fossula and arched tabellae. Comparatively little is known of the type species, *Cyathophyllum robustum* Hall (1877, Pl. 22, fig. 1-14) from the Givetian of New York, as there is no description of topotype material. The described later forms resemble *Tortophyllum* more than *Stathmoelasma* and are easily distinguished by their very different tabularium. The early forms are less distinct, but have a more prominent fossula and a slightly different tabularium.

Moravophyllum Kettnerova (1932, p. 29) from the Givetian of Czechoslovakia resembles *Stathmoelasma* in possessing a large cylindrical corallum, numerous long smooth septa and a shortened cardinal septum. In *Moravophyllum*, however, the septa are pinnately arranged in adult stages and the tabularium consists of convex tabellae apparently sloping towards the cardinal septum.

It is impossible to provide a definite statement on the differences between *Stathmoelasma* and *Ceratophyllum* Gürich (1896, p. 193) as *C. typus* (= *Cyathophyllum ceratites* Frech 1886), the type species of Gürich's genus, almost certainly includes more than one species. One of these (Frech 1886, Pl. 5 (17), fig. 4) has yard-arm carinae and, therefore, is not conspecific with *Stathmoelasma*; some of the others are less dissimilar but have a narrower dissepimentarium of more elongate dissepiments and have differently shaped tabulae.

There are several similarities between *S. amplum* and the American Givetian species *Tortophyllum milleri* Pittrat (1962, p. 1158, 1159, Pl. 158, fig. 7-10). However, most species of *Tortophyllum*, including the type *Zaphrentis cystica* Winchell (1866, p. 90), have a characteristic axial structure formed of inclined tabellae and long variably rotated septa (Sloss 1939, Stumm 1963).

Stathmoelasma amplum sp. nov.

(Pl. 31, fig. 1-5)

NAME DERIVATION: L. *amplus* = large.

MATERIAL: Holotype, UNE F8778. Paratypes 1-3, UNE F8779-8781. All were collected from the upper beds of the Sulcor Limestone (late Emsian, or possibly Eifelian) at the N. end of the Sulcor outcrop in Portion 249, Parish of Burdekin, County Inglis, N.S.W.

DIAGNOSIS: Corallum subcylindrical, large, up to 65 mm in diameter and more than 100 mm in length. Septa radially arranged, smooth, withdrawn axially and numbering from 52 × 2 to 60 × 2 at maturity; cardinal septum shorter than other major septa. Dissepiments relatively small and numerous. Tabulae broad and typically downturned at their periphery.

DESCRIPTION: Specimens in which the apical part of the corallum is preserved have not been collected. In adult stages the corallum is cylindrical and large, with a diameter of from 55 to 65 mm and a length of more than 100 mm. Details of the exterior are not available, but the dissepiments suggest that the calice is steep-sided and that there is no peripheral platform.

The epitheca is thin and, although it has perished in some of the types, it was probably originally entire.

The septa are smooth, radially arranged, and differentiated into two orders; in places they are discontinuous but, otherwise, are well developed.

Septal counts are as follows (measurements in mm):

Specimen	Mean diameter	No. of septa
UNE F8781	50	52 × 2
UNE F8778	58	54 × 2
UNE F8780	62	60 × 2
UNE F8779	63	60 × 2

The cardinal septum is shorter than the other major septa, which terminate from about 5 to 8 mm short of the axis. The minor septa typically extend one-half the distance to the axis and only just project into the tabularium.

Typically the dissepimentarium is from 8 to 15 mm wide. The dissepiments are relatively small and numerous and in transverse section tend to be rhomboid. In spite of the large size of the coral there are no lateral dissepiments.

The tabularium is one-half, or more, of the total width of the coral and consists of peripheral tabellae and central tabulae. The latter are broad and commonly are downturned peripherally.

REMARKS: Although this species has never been referred to *Mictophylllum*, it is introduced here because of its superficial similarity to *Loomberaphyllum postulosum* described below. Both occur in the Sulcor Limestone. The septa in *S. amplum* are shorter and they are neither dilated nor split peripherally as they are in *L. pustulosum*. The tabularium in the two species is also different; in *L. pustulosum* it consists entirely of small arched tabellae, whereas in *S. amplum* both peripheral tabellae and axial tabulae are present.

Family STERICTOPHYLLIDAE nov.

TYPE GENUS: *Sterictophyllum* nov., see below.

DIAGNOSIS: Corallum solitary, large, typically slightly elliptical in transverse section. Although there is no fossula, some, or all of the protosepta may be shorter than other major septa; carinae absent, or if present not of the yard-arm type. Trabeculae parallel, almost straight, and inclined at a low angle to the horizontal. Dissepiments small; dissepimentarium broad. A septa sterozone is present in some species. Except in the most primitive species, the tabularium consists of small arched tabulae, or tabellae, and tends to be broadly domed centrally.

REMARKS: The family is proposed for the new genera *Sterictophyllum* and *Loomberaphyllum*. These cannot be accommodated in the Zaphrentidae because of differences in the tabularium and their lack of yard-arm carinae. Nor does there seem to be a close phylogenetic relationship between them and early cyathophyllids such as *Tipheophyllum*. In the Bethanyphyllidae the tabularium is different and, although the cardinal septum is shortened, other protosepta are inconspicuous.

As with other families of Lower Devonian corals, the origin of the Sterictophyllidae is obscure and presumably will remain so until the very large gap that exists in our knowledge of late Silurian and early Devonian coral faunas is filled. The earliest known member of the family is probably an early Gedinnian species identified as *Phaulactis*, and indeed it is possible that the family was derived from the Halliidae.

Genus **Sterictophyllum** nov.

NAME DERIVATION: Gk στερικτός = firmly set, and φύλλον = leaf.

TYPE SPECIES: *Cyathophyllum cresswelli* Chapman, see below.

DIAGNOSIS: Corallum large, solitary, trochoid to cylindrical and elliptical in transverse section. Septa radially arranged, differentiated into two orders, faintly to moderately carinate and commonly sufficiently dilated peripherally to form a stereozone. Trabeculae fairly straight and set at a very low angle to the horizontal. Dissepiments numerous and relatively small. Tabularium in primitive species irregularly domed periaxially and composed of short arched tabulae; in advanced species the tabularium is elevated centrally and composed of arched tabellae.

ADDITIONAL SPECIES ASSIGNED: *Dohmophyllum pridianum* Philip 1962, p. 187, 188, Pl. 28, fig. 8, 9. Limestone in the Coopers Creek Formation (late Gedinnian, or Siegenian), Viet.

Sterictophyllum vallatum nom. nov. Occurrence as above.

SPECIES REQUIRING INVESTIGATION: *Cyathophyllum ungeri* Penecke 1894, p. 599, Pl. 8, fig. 9, 10. Barrandei-Schichten (Emsian) Austria.

Cyathophyllum sp., Merriam 1940, Pl. 12, fig. 2. *Pinyonensis* zone, Nevada Formation (Emsian according to Johnson 1962; House 1962, p. 252), Nevada.

Phaulactis cyathophylloides Bulvanker 1958 (*non* Ryder), Pl. 3, fig. 2. Tomchumysch Beds, Chumysh R., Kuznets Basin, USSR. Russian workers have not been in agreement on the age of the Tomchumysch Beds; Rzhonsnitskaya (1962) regards them as both Upper Silurian and Lower Gedinnian.

Tabulophyllum bifurcatum Soshkina 1939, p. 41, 42, 57, 58, Pl. 11, fig. 87, 88. Upper part of the limestones covering the Pashia ore-bearing beds (Frasnian), Middle Urals.

COMPARISONS: The type species was originally referred to *Cyathophyllum* and later removed to *Mictophyllum*. From *Cyathophyllum, Sterictophyllum* is distinguished by its solitary form and by the different arrangement of its trabeculae. Differences between *Mictophyllum* and *Sterictophyllum* are less obvious. In *Sterictophyllum* septal dilation is peripheral, whereas in *Mictophyllum* it is commonly at the inner margin, or middle part of the dissepimentarium and only very rarely is it peripheral. The trabeculae are not as flat in *Mictophyllum*, nor is the axial or periaxial elevation of the tabularium as marked as it is in *Sterictophyllum*. Reduction of the minor septa and consequent development of a herringbone dissepimentarium, which is typical in *Mictophyllum*, is rare in *Sterictophyllum* and, finally, there is a different relationship between the septa and the epitheca in the two genera.

One of the species referred to the new genus was originally placed in *Dohmophyllum* Wedekind (1923, p. 29, 35). Although the typical spongophyllid (*sensu* Pedder 1964) tabularium may be modified axially in Wedekind's genus, it is still fundamentally spongophylloid. *Dohmophyllum* is further distinguished by is steeply inclined trabeculae, rhopaloid septa, and feebly developed epitheca.

The genus *Briantia* Barrois (1889, p. 45), based on *B. repleta* from the Calcaire d'Erbray (Emsian according to Péneau 1962), France, resembles *Sterictophyllum* in some respects. However, the stereozone in *Briantia* occupies the entire marginarium and the trabeculae are said to be rhabdacanthine (Hill 1956b, p. 277).

Briantelasma Oliver (1960a, p. 89), with *B. americanum* an American Gedinnian species as its type, is another genus resembling *Sterictophyllum*. It is distinguished by having a more extensive stereozone and a weak cardinal fossula. In a subsequent diagnosis, Oliver (1960b, p. 6) stressed the importance of a pinnate septal arrangement in *Briatelasma*.

Chalcidophyllum, proposed earlier in this paper, differs from *Sterictophyllum* in its weakly aggregate growth form and axially sagging tabularium.

The figure of *Charactophyllum nanum*, the type species of *Charactophyllum* Simpson (1900, p. 209, 210), given by Stumm (1949, Pl. 12, fig. 11), suggests a similarity between that genus and *Sterictophyllum*. The principal differences between the genera are that, in *Charactophyllum*, septal dilation is axial rather than peripheral (Watkins 1959, Pl. 16, fig. 13-16) and the trabeculae are an entirely different shape (Wang 1950, Pl. 7, fig. 44).

Many solitary corals with peripherally dilated septa have been placed in *Temnophyllum* Walther (1928, p. 120). The trabeculae are dissimilar in several of these species and, as Wang (1948, p. 13) has pointed out, the genus is polyphyletic. The type species of *Temnophyllum* and its synonym *Temeniophyllum* Lang, Smith, and Thomas (1940, p. 131) is *T. latum* Walther (1928, p. 123, 124, Fig. 14). No description is available of the fine structure in topotypic material of the species; however, trabeculae have been described in a specimen from Devon (Middleton 1959, p. 155). In this specimen they are inclined inwards and upwards at between 10° and 30° to the horizontal and are not divergent. In species referred to *Temnophyllum* from the Middle Devonian of China and W. Australia (Yoh 1937, Wang 1948, Wang and Lee 1948, Hill 1954a) the trabeculae are not only more erect, and curved or divergent in the plane of the septum, but may also deviate from this plane. These species are further distinguished from *Temnophyllum sensu stricto* by their incompletely developed stereozone. Similar corals have also been described under other generic names. Among these are *Charactophyllum antiquum* Soshkina 1949, 1951, 1962 and *Cyathophyllum heterophylloides* Frech 1885, Reed 1922. It seems desirable that a new genus, or genera, be erected for all these species, but this is beyond the scope of the present work.

Although *Temnophyllum* has been listed in faunas from E. Australia (Hill in Hill and Denmead 1960, p. 151) and Nevada (Merriam 1963, p. 53), occurrences supported by description, or figures, are confined to Devon (Middleton 1959), the Eifel (Ma 1956, Pl. 6, fig. 1, as *Campophyllum*), the Harz Mountains (Walther 1928), the Urals (Soshkina 1951), and perhaps Algeria (Semenoff-Tian-Chansky 1961). The Algerian occurrence is probably Givetian but may be Frasnian; the others are Givetian.

Sterictophyllum and *Temnophyllum* are most easily distinguished by the nature of their sterozone and the tabularium. In *Sterictophyllum*, the stereozone is exterior to the dissepimentarium whereas, in *Temnophyllum*, it is developed in the dissepimentarium and may completely obscure the dissepiments. The tabulae in *Sterictophyllum* are elevated either axially or periaxially but, in *Temnophyllum*, the tabularium is normally depressed axially.

Sterictophyllum cresswelli (Chapman 1925)

(Pl. 32, fig. 1-7, 11; Pl. 33, fig. 1-6; Pl. 34, fig. 3, 4)

1925 *Cyathophyllum cresswelli* Chapman, p. 111, 112, Pl. 13, fig. 11-14.
1939a *Mictophylllum cresswelli* (Chapman) Hill, p. 246-248, Pl. 14, fig. 7-11.
non 1942b *Mictophyllum* cf. *cresswelli* Hill, p. 159, Pl. 3, fig. 9 (= *Loomberaphyllum pustulosum*).
1954b *Mictophyllum cresswelli* Hill, p. 109, Pl. 7, fig. 8 (= *Chalcidophyllum campanense*).
non 1962 *Mictophyllum* sp. aff. *M. cresswelli*, Philip, p. 180, Pl. 23, fig. 3, 4 (= *Sterictophyllum vallatum*).

MATERIAL: Holotype NMV P 1267 and P 1270 (pieces separately numbered). Paratype, NMV P 1271. Hypotypes, AM F1242, NMV P 22988-22992, P 22994, P 22998, P 23000, P 23001, P 23007. All these specimens were collected from the Lilydale Limestone (Siegenian) at Cave Hill, Lilydale, Vict.

DIAGNOSIS: Corallum ceratoid to cylindrical in adult stages, with a known maximum diameter of 34 mm. Septal stereozone present in some individuals. Septa radially arranged and in mature specimens numbering from about 33 × 2 to 39 × 2. Trabeculae nearly flat. Dissepiments numerous. Tabularium with marginal tabellae and short, commonly periaxially domed tabulae.

DESCRIPTION: The corallum is simple and according to Hill (1939a, p. 246) at first may be patellate and curved. The early stages are not preserved in any of the specimens seen by the writer; in later stages the corallum is invariably ceratoid to subcylindrical and is essentially erect rather than curved. Transverse sections commonly are just elliptical and, in the material studied, reach a maximum mean diameter of 29 mm (NMV P 22988). Hill (1939a, p. 247, however, examined a specimen having a diameter of as much as 34 mm. The longest specimen seen (NMV P 22994), although incomplete both proximally and distally, is 85 mm in length. Rejuvenscence occurs, but in most cases the resultant change in diameter is slight.

The calice is not known at the present time. Longitudinal sections suggest that it is steep-sided and has an axial boss. The exterior of the epitheca bears faint septal grooves and abundant fine growth striae.

The wall is variable, in some specimens it consists of an epitheca which is confluent with the peripheral part of the septa, and is less than 1 mm thick. In others the epitheca is supplemented by a septal stereozone forming a wall up to 2 mm thick. Hill's material suggested that the peripheral septal dilation decreases as the height of the corallum increases and that no continuous stereozone is present in later stages. However, a study of more abundant material has not confirmed this; but it does reveal that a peripheral stereozone is most likely to be developed in individuals having a large number of septa relative to the diameter.

The septa are radially arranged and well differentiated into two orders. Details of the septa and wall are summarized in the following table (measurements in mm):

Specimen	Mean diameter	No. of septa	Wall thickness	Stereozone
NMV P 22998	15	34 × 2	eroded	absent?
NMV P 22989	18	32 × 2	0·6	absent
NMV P 23007	20	32 × 2	0·8	absent
NMV P 22998	20	33 × 2	eroded	absent?
NMV P 22992	20	33 × 2	0·4 and 0·8	present in part
NMV P 22990	20	36 × 2	1·8	present
NMV P 23007	23	33 × 2	0·8	absent
AM F1242	23	38 × 2	2·0	present
NMV P 22991	25	38 × 2	0·7	absent
NMV P 23001	26	36 × 2	0·8	absent
NMV P 23000	27	39 × 2	1·9	present
NMV P 22988	29	35 × 2	0·5	absent

Both major and minor septa are faintly carinate and dilated in the dissepimentarium. The major terminate at or near the axis, and in the tabularium are thin and wavy, so that the interseptal loculi vary considerably in width. The minor septa are normally one-third to one-half the length of the major and may either just project into the tabularium or be confined to the dissepimentarium. The trabeculae are inclined at a very low angle to the horizontal and in some cases are almost normal to the wall.

Although variable, the dissepiments, on the whole, are numerous and relatively small. They may be coated with sclerenchyme and in some transverse sections (NMV P 23000 and P 23001) a prominent ring of sclerenchyme is developed in the central part of the dissepimentarium. There is a tendency for the dissepiments to cross the interseptal loculi obliquely, but this never leads to the formation of a herringbone dissepimentarium.

Tabellae, which in some cases are difficult to distinguish from dissepiments, occur at the margin of the tabularium in most specimens. The tabulae are short and tend to be periaxially domed.

REMARKS: A specimen from the Kuznets Basin, figured by Bulvanker (1958, Pl. 3, fig. 2) as *Phaulactis cyathophylloides*, closely resembles *Sterictophyllum cresswelli* and there is little doubt that the species are congeneric. It is less close to *P. cyathophylloides* Ryder, which has recently been restudied by Minato (1961, p. 55), but nevertheless suggests that *Sterictophyllum* was derived from *Phaulactis*.

Sterictophyllum vallatum nom. nov.

1962 *Mictophylllum* sp. affin. *M. cresswilli* Philip p. 180, Pl. 23, fig. 3, 4.

NAME DERIVATION: L. *vallatus* = walled.

MATERIAL: Holotype, UM thin sections 1543, 4 cut from the same coral.

DIAGNOSIS: Corallum ceratoid. Peripheral stereozone well developed in the holotype (2·5 mm wide). Septa withdrawn from the axis and numbering about 42 × 2 at 30·0 mm. Dissepiments small and numerous. Tabularium axially elevated and composed entirely of arched tabellae.

REMARKS: In spite of the paucity of the material, a name is proposed for this coral since it is clearly distinct from other described species.

It differs from *S. cresswelli* in its large size, shorter and more numerous septa, and by its relatively wider and more axially elevated tabularium. In the unique specimen, the peripheral stereozone is broader than in any known specimen of *S. cresswelli*; however, the width of the stereozone is expected to be variable.

S. pridianum, which occurs in the same limestone, is similar in some respects, but is subcylindrical and has longer and much more strongly carinate septa than *S. vallatum*.

Genus **Loomberaphyllum** nov.

NAME DERIVATION: Parish of Loomberah, and Gk φύλλον = leaf.

TYPE SPECIES: *Loomberaphyllum pustulosum* sp. nov., see below.

DIAGNOSIS: Corallum large, subcylindrical, generally elliptical, rather than circular, in transverse section. Septa long, but cardinal and some, or all of the other protosepta, are shorter than their adjacent major septa. Septa of both orders are smooth or nearly so; towards the periphery they become progressively more dilated and tend to split into two or three separate lamellae. Trabeculae parallel and set at a low angle to the horizontal. Dissepiments relatively small, numerous, forming a broad dissepimentarium; dilation of the septa may spread to the dissepiments, especially near the periphery. Tabularium elevated axially and composed of numerous, mostly arched tabellae.

ADDITIONAL SPECIES ASSIGNED: *Loomberaphyllum impensum* nom. nov., see below.

COMPARISONS: *Loomberaphyllum* is distinguished from *Sterictophyllum* by its shortened protosepta and by the tendency for its septa to split peripherally.

The coral described as *Radiophyllum arborescens* from the Mt Etna Limestone (Emsian) of Queensland (Hill 1942a, p. 17, 18, Pl. 1, fig. 7) has features in common with both *Loomberaphyllum* and *Sterictophyllum* and is almost certainly a sterictophyllid. Since *Entelophyllum arborescens* Hill and Jones (1940, p. 188, Pl. 3, fig. 5) is the type species of *Radiophyllum* Hill (1942a, p. 17), it might appear that the two new genera are close to *Radiophyllum*, but this is probably not so. Strusz (1963), who has had the opportunity of collecting additional topotypes of *R. arborescens* from the Lower Devonian Garra Beds of N.S.W., maintains that it is close to *Entelophyllum* and is not conspecific with the Queensland specimen.

The way in which the septa split peripherally in *Loomeraphyllum* is reminiscent of the cyathophyllids. In the Cyathophyllidae, however, the trabeculae are steeply inclined and the radial symmetry is more pronounced, since the protosepta are indistinct in adult stages.

Loomberaphyllum pustulosum sp. nov.

(Pl. 32, fig. 8, 9; Pl. 34, fig. 7, 9)

1942b *Mictophylllum* cf. *cresswelli* (Chapman) Hill, p. 159, Pl. 3, fig. 9.
non 1925 *Cyathophylllum cresswelli* Chapman, p. 111, 112, Pl. 13, fig. 11-14.

NAME DERIVATION: L. *pustulosus* = full of pustules.

MATERIAL: Holotype, UNS F8796. Loomberah Limestone (late Emsian or early Eifelian), Portion 58, Parish of Loomberah, County of Parry, N.S.W.

DIAGNOSIS: Corallum subcylindrical, large, typically 50 to 55 mm in diameter. Except for the cardinal, counter and four other septa (also protosepta?), which are shorter, the major septa extend to the axial region. Septa of both orders are dilated in the dissepimentarium; peripherally the major tend to split into more than one lamella. Septal counts 51 × 2 to 53 × 2 in known specimens. Dissepiments small and numerous. Sclerenchymal investment of both septa and dissepiments is common at the periphery. Tabularium broadly domed and entirely constituted of small arched tabellae.

DESCRIPTION: The holotype is a subcylindrical fragment of a large solitary coral, which before sectioning was about 50·0 mm long and 48·0 mm in mean diameter. It was completely embedded in matrix and had been eroded prior to fossilization.

A small part only of the epitheca is preserved; it is 1·0 mm thick. The septa appear to be embedded in the epitheca and are differentiated into two orders. Septal counts are as follows (measurements in mm):

Specimen	Mean diameter	No. of septa
US 7247, 7285	40-55	51 × 2
UNE F8696	48	53 × 2

The cardinal, counter and four other septa, which are so situated that they may also be protosepta, are relatively short. The remaining major septa extend in groups to the axial region where they are slightly twisted. The minor septa are about one-half the length of the major septa and typically terminate at the inner margin of the dissepimentarium. In the tabularium the septa are thin and smooth, but in the dissepimentarium those of both orders are dilated and weakly carinate. Near the periphery additional trabeculae may be developed on the major septa and vacuoles may appear along the median plane of the septa. Also near the periphery the septa may be invested with light coloured lamellar sclerenchyme which spreads to the dissepiments. The trabeculae are very flat lying, making an angle of up to only 10° or 15° with the horizontal.

The dissepimentarium is broad and consists of about 20 rows of small globose dissepiments. Lateral dissepiments occur near the periphery.

There are no tabulae; the tabularium is composed entirely of small arched tabellae. At the margin these are flat or outwardly sloping, but towards the axis they become horizontal so that the tabularium is broadly domed. Thin sclerenchyme invests many of the tabellae.

REMARKS: Although the specimen from the Loomberah Limestone described by Dun (in Benson 1918, p. 376, 377, Fig. 4) as *Cyathophyllum* sp. shares some features with *L. pustulosum*, it has more numerous septa and is probably a distinct species.

Loomberaphyllum impensum nom. nov.

(Pl. 34, fig. 10)

1962 *Acanthophyllum clermontensis* (Etheridge) Phillip, p. 185, 186, Pl. 27, fig. 1, 2.
non 1911 *Cyathophyllum* (?) *clermontensis* Etheridge, p. 5, 6, Pl. B, fig. 1, 2; Pl. D, fig. 3.

NAME DERIVATION: L. *impensus* = great.

MATERIAL: Holotype, UM 3037 from which two thin sections have been prepared—TS 1599 and TS 1600. This was collected from a limestone in the Coopers Creek Formation (late Gedinnian or Siegenian) on Tyers R., Vict.

REMARKS: The holotype has been described and figured by Philip. The main difference between it and *Acanthophyllum clermontense*, which has been redescribed by Hill (1939b, p. 57, 58, Pl. 4, fig. 1, 2), lies in the tabularium. In *A. clermontense* the tabulae are normal for the genus, that is to say, they are close-set and are depressed axially; in *L. inpensum*, on the other hand, they tend to be convex and are elevated axially. Furthermore, the protosepta are not discernible in *A. clermontense* as they are in *L. impensum.*

Loomberaphyllum pustulosum is a smaller species with more uniformly convex tabellae and fewer lateral dissepiments.

Family CYATHOPHYLLIDAE Dana

Genus **Cavanophyllum** nov.

NAME DERIVATION: Cavan Station, and Gk φύλλον = leaf.

TYPE SPECIES: *Mictophyllum trochoides* Hill, see below.

DIAGNOSIS: Corallum large, solitary. Septa long, weakly rotated at the axis, thin and smooth or faintly carinate, except near the periphery where, due to trabecular deviation, subsidiary lamellae, dilation, pronounced carinae, and internal spaces are developed. Dissepiments abundant. Tabulae incomplete forming a broadly domed tabularium.

COMPARISONS: Birenheide (1963) has provided new descriptions of several genera and species related to *Cavanophyllum trochoides*. In the light of his work, *Cavanophyllum* is distinguished from *Cyathophyllum* Goldfuss (1826, p. 54) by its long, axially rotated septa containing almost spherical vacuoles, and by its centrally domed tabularium. The type species are further distinguished by their growth form, although Birenheide includes both solitary and colonial forms in *Cyathophyllum.*

Peripaedium Ehrenberg (1834, p. 384) and the synonymous genera *Keriophyllum* Wedekind (1923, p. 27, 34) and *Ceriophyllum* Lang, Smith and Thomas (1940, p. 35), resemble *Cavanophyllum*. They are distinguished by their septa, which peripherally, are thin and very much less modified.

Tipheophyllum Hill (1956a, p. 9) is probably the closest described genus to

Cavanophyllum. The septa in *Tipheophyllum ops* Philip from the Coopers Creek and Lilydale Limestones strongly resemble those of *C. trochoides*. The genera are distinguished by the phaceloid growth form and more uniform carinae in *Tipheophyllum*.

Mictophyllum differs from the new genus in several respects, but is most easily distinguished by its unmodified septa.

Cavanophyllum trochoides (Hill 1940)

(Pl. 33, fig. 7-10; Pl. 34, fig. 5, 8, 11, 12)

1940 *Mictophylllum trochoides* Hill, p. 265, 266, Pl. 11, fig. 7-10.

MATERIAL: Holotype, AM F17110, probably from the Cavan Bluff Formation (Siegenian) at Cavan, near Taemas on the Murrumbidgee R., N.S.W. Paratypes, UQ F4221, F4222, Cavan Bluff Formation, Clear Hill, near Taemas, and UQ F4260, same formation on Wee Jasper Rd 0·5 mile from Taemas Bridge (1937), N.S.W. Hypotypes 1-3, UNE F8782-8784, Cavan Bluff Formation, Clear Hill, near Taemas. Hypotype 4, UNE F8785, limestone containing the Cavan Bluff fauna (e.g. *Zelolasma gemmiforme* and *Tipheophyllum bartrumi*), E. of the bridge over the Goodradigbee R. at Wee Jasper, N.S.W.

DIAGNOSIS: Corallum trochoid to cylindrical, up to 50 mm in diameter. Septa long, smooth to faintly carinate, radially arranged; at maturity, septal counts vary from about 37 × 2 to 46 × 2 and there is a strong tendency peripherally for the septa to split into separate lamellae; these may re-unite leaving internal spaces in the septum. Dissepiments relatively small, abundant, and periodically invested with thin sclerenchyme. Tabulae incomplete forming a broadly domed tabularium.

DESCRIPTION: The corallum is trochoid to cylindrical; the largest seen to date (UNE F8782) was obviously very incomplete, yet before sectioning had a mean diameter of about 50 mm and a length of 60 mm. The specimens collected so far are either eroded or embedded in matrix, or both, and no details of the exterior of the coral are available. Longitudinal sections suggest that the calice is steep-sided and that there is no peripheral platform.

The epitheca is variable, but generally thin.

The septa are radially arranged and clearly differentiated into two orders. They are smooth, or faintly carinate, and thin, except in the outer part of the dissepimentarium where they are dilated. The peripheral parts, in ephebic and gerontic stages, are commonly broken into separate lamellae, which may re-unite leaving internal spaces. Septal counts are as follows (measurements in mm):

Specimen	Mean diameter	No. of septa
AM F17110	22	38 × 2
UNE F8783	27	36 × 2
UNE F8784	28	37 × 2
UNE F8784	34	41 × 2
UNE F8783	38	37 × 2
UNE F8785	40	38 × 2
UQ F4221	45	42 × 2
UNE F8782	48	46 × 2

The major septa are unequally long and typically terminate near the axis; in many specimens they form a weak axial vortex. The minor septa are as well developed as the major in the dissepimentarium, but either fail to enter the tabularium, or only just project into it. The trabeculae lie at an angle of about 35° to the horizontal in the disseptimentarium, but tend to steepen slightly on entering the tabularium. Due to the peculiar break up of the septa, the trabeculae, in places, appear to be discrete in transverse sections.

The dissepiments are numerous and small relative to the size of the corallum. As seen in transverse section they are commonly chevron-shaped, or cross the interseptal loculi obliquely and, particularly in the peripheral region, may abut against a more peripherally situated dissepiment rather than a neighbouring septum. At intervals they are coated with a thin layer of sclerenchyme. The width of the dissepimentarium is about one-half the radius of the tabularium.

The tabulae are close-set and incomplete; in most specimens the tabularium is broadly domed.

REMARKS: At the present time, this is the only species referred to the genus. A few species of *Cyathophyllum* from the Eifelian of Germany, such as *C. degener* (Haller 1936, p. 620, Pl. 36, fig. 2) and *C. spongiosum* (Schulz 1883, p. 237, Pl. 21, fig. 8) have features in common with *Cavanophyllum trochoides*, but are distinguished by their size, or septal counts, as well as by the criteria cited as distinguishing the genera.

References

BARROIS, CHARLES, 1889. Faune du Calcaire d'Erbray (Loire Inférieure). *Mém. Soc. géol. Nord* 3: 1-348, Pl. 1-17.

BELYEA, H. R., and MCLAREN, D. J., 1962. Upper Devonian formations, southern part of Northwest Territories, northeastern British Columbia, and northwestern Alberta. *Pap. geol. Surv. Can.* 61-29.

BENSON, W. N., 1918. The geology and petrology of the great serpentine belt of New South Wales. 7, The geology of the Loomberah district and a portion of the Goonoo Goonoo Estate. *Proc. Linn. Soc. N.S.W.* 43: 320-60, 363-384, Pl. 31-38.

BIRENHEIDE, RUDOLF, 1963. *Cyathophylllum*-und *Dohmophyllum*-Arten (Rugosa) aus dem Mitteldevon der Eifel. *Senckenbergiana Lethaea* 44: 363-458, Pl. 46-62.

BULVANKER, E. Z., 1958. *Devonian Tetracorals from the vicinity of the Kuznets Basin* (in Russian), text and plates, Leningrad.

CHAPMAN, FREDERICK, 1925. New or little-known fossils in the National Museum. 28, Some Silurian rugose corals. *Proc. Roy. Soc. Vict.* 37: 104-118, Pl. 12-15.

CLAUSS, K. A., 1956. Über Oberdevon-Korallen von Menorca. *Neues Jb. Min. Geol. Paläont.* 103: 5-27, Pl. 1, 2.

EHRENBERG, C. G., 1834. Beiträge zur physiologischen Kenntniss der Corallenthiere im allgemeinen, und besonders des rothen Meeres, nebst einem Versuche zur physiologischen Systematik derselben. *Abh. preuss. Akad. Wiss.* (1832): 225-380. Also printed separately with different pagination as: *Die Corallenthiere des Rothen Meeres physiologisch und systematisch verzeichnet*, Berlin. Neither has been seen, the information was taken from Lang, Smith, and Thomas.

ETHERIDGE, ROBERT (*fil.*), 1911. The Lower Palaeozoic corals of Chillagoe and Clermont, 1. *Publ. Qd. geol. Surv.* 231.

FLOWER, R. H., 1961. Montoya and related colonial corals. *Mem. New Mexico State Bur. Mines.* 7.

FRECH, FRITZ, 1885. Die Korallenfauna des Oberdevons in Deutschland. *Z. dtsch. geol. Ges.* 37: 21-130, Pl. 1-11.

————, 1886. Die Cyathophylliden und Zaphrentiden des deutschen Mitteldevon. *Paleont. Abh.* 3: 115-234, Pl. 13-20.

GOLDFUSS, G. A., 1826-1833. *Petrefacta Germaniae*, Düsseldorf.

GÜRICH, GEORG, 1896. Das Palaeozoicum des polnischen Mittelgebirges. *Verh. Russ-Kais. min. Ges. St. Petersburg* 32.

HALL, JAMES, 1877 (1876 on cover). *Illustrations of Devonian fossils: Gastropoda, Pteropoda, Cephalopoda, Crustacea and corals of the Upper Helderberg, Hamilton and Chemung Groups.* Geol. Surv. N.Y., Albany.

HALLER, W., 1936. Einiger biostratigraphische untersuchungen in der Rohrer Mulde unter besonderer Berücksichtigung der Keriophyllen. *Jb. preuss geol. Landesanst.* 56: 590-632, Pl. 32-43.

HILL, DOROTHY, 1939a. The Devonian rugose corals of Lilydale and Loyola, Victoria. *Proc. Roy. Soc. Vict.* 51: 219-256, Pl. 13-16.

————, 1939b. The Middle Devonian rugose corals of Queensland. 1, Douglas Creek and Drummond Creek, Clermont district. *Proc. Roy. Soc. Qd.* 50: 55-65, Pl. 4, 5.

————, 1940. The Lower Middle Devonian rugose corals of the Murrumbidgee and Goodradigbee Rivers, N.S.W. *J. Roy. Soc. N.S.W.* 74: 247-276, Pl. 9-11.

————, 1942a. The Lower Devonian rugose corals from the Mt Etna Limestone, Queensland. *Proc. Roy. Soc. Qd.* 54: 13-22, Pl. 1.

————, 1942b. The Devonian rugose corals of the Tamworth district, N.S.W. *J. Roy. Soc. N.S.W.* 76: 142-164, Pl. 2-4.

————, 1950. Middle Devonian corals from the Buchan district, Victoria. *Proc. Roy. Soc. Vict.* 62: 137-164, Pl. 5-9.

————, 1954a. Coral faunas from the Silurian of New South Wales and the Devonian of Western Australia. *Bull. Bur. Min. Resour. Aust.* 23.

————, 1954b. Devonian corals from Waratah Bay, Victoria. *Proc. Roy. Soc. Vict.* 66: 105-118, Pl. 6-9.

————, 1956a. Paleozoic corals from New Zealand. 1, The Devonian corals of Reefton, New Zealand. *Paleont. Bull, N.Z.* 25: 5-14, Pl. 1, 2.

————, 1956b. Rugosa. In *Treatise on invertebrate paleontology*, Lawrence F: 233-324.

HILL, DOROTHY, and DENMEAD, A. K. (editors), 1960. The geology of Queensland. *J. geol. Soc. Australia* 7.

HILL, DOROTHY, and JONES, O. A., 1940. The corals of the Garra Beds, Molong district, New South Wales. *J. Roy. Soc. N.S.W.* 74: 175-208, Pl. 2-8.

HOUSE, M. R., 1962. Observations on the ammonoid succession of the North American Devonian. *J. Paleont.* 36: 247-284, Pl. 43-48.

JOHNSON, J. G., 1962. Lower Devonian-Middle Devonian boundary in central Nevada. *Bull. Amer. Assoc. petrol. Geol.* 46: 542-546.

KETTNEROVA, MARIE, 1932. Palaeontological studies of the Devonian of Čelechovica (Moravia), 4 Rugosa (Czech with English summary). *Práce geol.-palaeont. úst. Karlovy Univ. v. Praze* 1932: 3-94, Pl. 1-5.

LANG, W. D., and SMITH, STANLEY, 1939. Some new generic names for Palaeozoic corals. *Ann. Mag. nat. Hist.*, ser. 11, 3: 152-156, Pl. 4.

LANG, W. D., SMITH, STANLEY, and THOMAS, H. D., 1940. *Index of Palaeozoic coral genera.* British Museum, London.

MA, T. Y. H., 1956. A reinvestigation of climate and the relative positions of continents during the Devonian. *Res. past Climate cont. Drift* 9.

McLAREN, D. J., MORRIS, A. W., and McGREGOR, D. C., 1962. Illustrations of Canadian fossils, Devonian of western Canada. *Pap. geol. Surv. Can.* 62-4.

MERRIAM, C. W., 1940. Devonian stratigraphy and paleontology of the Roberts Mountains region, Nevada. *Spec. Pap. geol. Soc. Amer.* 25.

————, 1963. Paleozoic rocks of Antelope Valley, Eureka and Nye Counties, Nevada. *Prof. Pap. U.S. geol. Surv.* 423.

MIDDLETON, G. V., 1959. Devonian tetracorals from south Devonshire, England. *J. Paleont.* 33: 138-160, Pl. 27.

MINATO, M., 1961. Ontogenetic study of some Silurian corals of Gotland. *Stockholm Contri. Geol.* 8 (4).

OLIVER, W. A., 1960a. Rugose corals from reef limestones in the Lower Devonian of New York. *J. Paleont.* 34: 59-100, Pl. 13-19.

————, 1960b. Devonian rugose corals from northern Maine. *Bull. U.S. geol. Surv.* 1111-A.

ORLOV, YU. A. (chief editor), 1962. *Principals of Paleontology; Porifera, Archeocyatha, Coelenterata, Vermes* Acad. Sci., Moscow.

PEDDER, A. E. H., 1964. Correlation of the Canadian Middle Devonian Hume and Nahanni Formations by tetracorals. *Palaeontology* 7: 430-451, Pl. 62-73.

————, 1965. Some North American species of the Devonian tetracoral *Smithiphyllum.* ibid. (in press).

PENEAU, JOSEPH, 1962. Silurien Supérieur et Dévonian Inférieur dans le sud-est du Massif Armoricain. In *Symposiums-Band*, 2, *Internationale Arbeitstagung über die Silur/Devon-Grenze* ---, Stuttgart: 191-201.

PENECKE, K. A., 1894. Das Grazer Devon. *Jb. geol. Reichsanst.* (*Bundesanst.*) Wien 43: 567-616, Pl. 7-12.

Philip, G. M., 1960. Victorian Siluro-Devonian faunas and correlations. *Rept. XXI Congr. geol. intern.* 7: 143-157.

———, 1962. The palaeontology and stratigraphy of the Siluro-Devonian sediments of the Tyers area, Gippsland, Victoria. *Proc. Roy. Soc. Vict.* 75: 123-246, Pl. 11-36.

Philip, G. M., and Pedder, A. E. H., 1964. A re-assessment of the age of the Middle Devonian of south-eastern Australia. *Nature* 202 (4939): 1323, 1324.

Pitrat, C. W., 1962. Devonian corals from the Cedar Valley Limestone of Iowa. *J. Paleont.* 36: 1155-1162, Pl. 158, 159.

Reed, F. R. C., 1922. Devonian fossils from Chitral and the Pamirs. *Paleont. indica* 6.

———, 1927. Palaeozoic and Mesozoic fossils from Yun-nan. ibid. 10.

Rzhonsnitskaya, M. A., 1962. Devonian intervals of the principal sections of Siberia and their correlation with the Devonian of Europe (in Russian). *Sovet. Geol.* 10: 16-27. Translated 1964. *Internat. geol. Rev.* 6: 1085-1098.

Schulz, Eugen, 1883. Die Eifelkalkmulde von Hillesheim. *Jb. preuss. geol. Landesanst.* 1882: 158-250, Pl. 19-23.

Semenoff-Tian-Chansky, Pierre, 1962. Madréporaires paléozoïques. In: Madréporaires du Dévonien du Chénoua (Algérie). *Bull. geol. Soc. Fr.*, sér. 7, 3: 292-313, Pl. 9.

Simpson, G. B., 1900. Preliminary descriptions of new genera of Paleozoic rugose corals. *Bull. N.Y. St. Mus.* 39 (8): 199-222.

Sloss, L. L., 1939. Devonian rugose corals from the Traverse Beds of Michigan. *J. Paleont.* 13: 52-73, Pl. 9-12.

Smith, Stanley, 1945. Upper Devonian corals of the Mackenzie River region, Canada. *Spec. Pap. geol. Soc. Amer.* 59.

Soshkina, E. D., 1939. Upper Devonian corals Rugosa of the Ural. *Akad. Nauk SSSR, paleont. Inst. Trudy* 9.

———, 1949. Devonian rugose corals of the Urals (in Russian). ibid. 15.

———, 1951. Late Devonian rugose corals, their systematics and evolution (in Russian). ibid. 34.

———, 1952. Key to the Devonian Tetracorals (in Russian). ibid. 39.

———, 1954. Devonian tetracorals of the Russian Platform (in Russian). ibid. 52.

Stewart, G. A., 1938. Middle Devonian corals of Ohio. *Spec. Pap. geol. Soc. Amer.* 8.

Strusz, D. L., 1963. Studies in the palaeontology, petrography and stratigraphy of the Garra Beds. Unpublished Ph.D. thesis, University of Sydney.

Stumm, E. C., 1937. The Lower Middle Devonian tetracorals of the Nevada Limestone. *J. Paleont.* 11: 423-443, Pl. 53-55.

———, 1949. Revision of the families and genera of the Devonian tetracorals. *Mem. geol. Soc. Amer.* 40.

———, 1960. New rugose corals from the Middle and Upper Devonian of New York. *J. Paleont.* 34: 161-163, Pl. 30.

———, 1963. Corals of the Traverse Group of Michigan. 11. *Tortophyllum, Bethanyphyllum, Aulacophyllum,* and *Hallia. Contri. Mus. Geol. Univ. Mich.* 18: 135-155, Pl. 1-10.

Sun, Y. C., 1958. The Upper Devonian coral faunas of Hunan. *Paleont. sinica* B, 8: 1-28, Pl. 1-12.

Walther, Conrad, 1928. Untersuchungen über die Mitteldevon-Oberdevongrenze. *Z. dtsch. geol. Ges.* 80: 97-152.

Wang, H. C., 1948. The Middle Devonian rugose corals of eastern Yunnan. *Contr. geol. Inst. natn. Univ. Peking* 33.

———, 1950. A revision of the Zoantharia Rugosa in the light of their minute skeletal structures. *Phil. Trans.* ser. B, 234: 175-246, Pl. 4-9.

Wang, H. C., and Lee, K. Y., 1948. Some Middle Devonian rugose corals from Tushan and Tuyun, Kueichow. In *Natn. Univ. Peking, fiftieth Anniv. Pap., geol. Ser.*: 103-11, Pl. 1.

Wang, H. C., et al., 1957. *Chinese standard fossils, invertebrate animals* (in Chinese). Peking.

Watkins, J. L., 1959. On the identity of the Devonian rugose coral genus *Diversophyllum* with *Tabulophyllum*, and notes on the genus *Charactophyllum. J. Paleont.* 33: 81, 82, Pl. 16.

Wedekind, Rudolf, 1923. Die Gliederung des Mitteldevons auf Grund von Korallen. *S.B. Ges. ges. Naturw. Marburg*, 1922 4: 24-35.

———, 1925. Das Mitteldevon der Eifel. Eine biostratigraphische Studie. 2, Materialen zur Kenntnis des mittleren Mitteldevon. *Schr. Ges. ges. Naturw. Marburg* 14.

Winchell, Alexander, 1866. *The Grand Traverse Region.* Mich. Geol. Surv., Ann Arbor.

Yoh, Sen-Shing, 1937. Die Korallenfauna des Mitteldevons aus der Provinz Kwangsi Südchina. *Palaeontographica* A, 87: 45-76, Pl. 4-9.

Explanation of Plates

L.S. and T.S. are the abbreviations used throughout for longitudinal and transverse sections respectively.

Plate 30

All figures × 1·5

Fig. 1, 3-5—*Chalcidophyllum campanense* var. *nanum* gen., sp. et var. nov. (1) UNE F8793, Paratype 7, L.S.; (3, 5) UNE F8792, Paratype 6, T.S.; (4) UNE F8792, Paratype 6, L.S. Both from the Bell Point Limestone, Vict.

Fig. 2, 6-13—*Chalcidophyllum campanense* gen. et. sp. nov. (2) UNE F8787, Paratype 1, L.S.; (6) UNE F8786, Holotype, L.S. of corallite on the left of 11; (7) UNE F8788, Paratype 2, L.S.; (8) UNE F8786, Holotype, T.S.; (9) UNE F8790, Paratype 4, T.S.; (10) UNE F8787, Paratype 1, L.S. of same corallite as fig. 13; (11) UNE F8786, Holotype, T.S.; (12) UNE F8786, Holotype, L.S. of corallite in centre of fig. 11; (13) UNE F8787, Paratype 1, T.S. All from the Bell Point Limestone, Vict.

Fig. 14, 15—*Chalcidophyllum discorde* gen. et sp. nov. (14) UNE F8795, Holotype, L.S.; (15) UNE F8795, Holotype, T.S.

Plate 31

All figures × 1·5

Fig. 1-5—*Stathmoelasma amplum* gen. et sp. nov. (1) UNE F8779, Paratype 1, T.S.; (2) UNE F8778, Holotype, T.S.; (3) UNE F8780, Paratype 2, T.S.; (4) UNE F8778, Holotype L.S.; (5) UNE F8780, Paratype 2, L.S. All from the upper part of the Sulcor Limestone, N.S.W.

Plate 32

All figures × 1·5

Fig. 1-7, 11—*Sterictophyllum cresswelli* (Chapman) gen. nov. (1) NMV P 22990, Hypotype, T.S.; (2) NMV P 23000, Hypotype, T.S.; (3) NMV P 23007, Hypotype, T.S.; (4) NMV P 22992, Hypotype, T.S.; (5) NMV P 23000, Hypotype, L.S.; (6) NMV P 23007, Hypotype, T.S.; (7) NMV P 22991, Hypotype, L.S.; (11) NMV P 22990, Hypotype, L.S. All topotypes from the Lilydale Limestone, Vict.

Fig. 8, 9—*Loomberaphyllum pustulosum* gen. et sp. nov. (7) UNE F8796, Holotype, T.S.; (8) UNE F8796, Holotype, L.S. Loomberah Limestone, N.S.W.

Fig. 10—*Stathmoelasma amplum* gen. et sp. nov., UNE F8779, Paratype 1, L.S. Upper part of the Sulcor Limestone, N.S.W.

Plate 33

All figures × 1·5

Fig. 1-6—*Sterictophyllum cresswelli* (Chapman) gen. nov. (1) NMV P 22998, Hypotype, T.S.; (2) NMV P 23007, Hypotype, T.S.; (3) NMV P 22989, Hypotype, T.S.; (4) NMV P 22991, Hypotype, T.S.; (5) NMV P 22988, Hypotype, T.S.; (6) NMV P 23001, Hypotype, T.S. All topotypes from the Lilydale Limestone, Vict.

Fig. 7-10—*Cavanophyllum trochoides* (Hill) gen. nov. (7) UNE F8784, Hypotype, L.S.; (8) UNE F8782, Hypotype, T.S.; (9) UNE F8784, Hypotype, T.S.; (10) UNE F8783, Hypotype, L.S. All topotypes from the Cavan Bluff Limestone, N.S.W.

Plate 34

All figures × 5

Fig. 1—*Chalcidophyllum discorde* gen. et sp. nov. UNE F8795, Holotype, T.S. Bell Point Limestone, Vict.

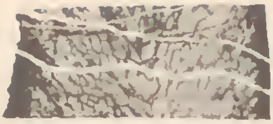
Fig. 2—*Chalicodphyllum campanense* gen. et sp. nov. UNE F8786, Holotype, T.S. Bell Point Limestone, Vict.

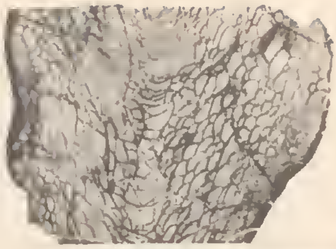
Fig. 3, 4—*Sterictophyllum cresswelli* (Chapman) gen. nov. (3) NMV P 22992, Hypotype, T.S. of a specimen lacking a stereozone; (4) NMV P 23000, Hypotype, T.S. of specimen possessing a stereozone. Both topotypes from Lilydale Limestone, Vict.

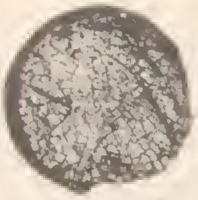
Fig. 5, 8, 11, 12—*Cavanophyllum trochoides* (Hill) gen. nov. (5) UNE F8784, Hypotype, tangential section near the periphery; (8) UNE F8782, Hypotype, tangential section near the periphery; (11) UNE 8784, Hypotype, T.S. All near topotypes from the Cavan Bluff Limestone, N.S.W. (12) UNE F8785, Hypotype, T.S. Limestone containing the fauna of the Cavan Bluff Formation at Wee Jasper, N.S.W.

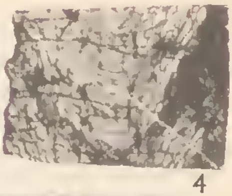
Fig. 6—*Sterictophyllum pridianum* (Philip) gen. nov. UM 3039, TS 1613, Holotype, T.S. Limestone in the Coopers Creek Formation, Vict.

Fig. 10—*Loomberaphyllum impensum* nom. nov. UN 3037, TS 1599, Holotype, T.S. Limestone in the Coopers Creek Formation, Vict.

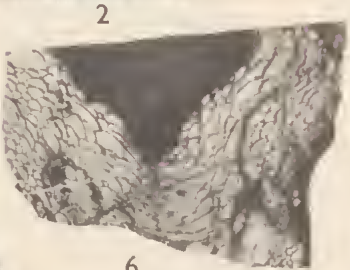

1

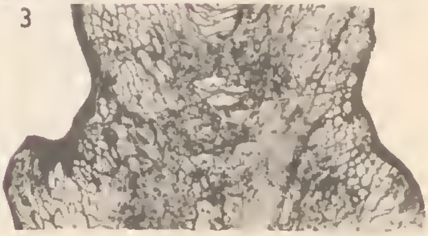

2


3


4

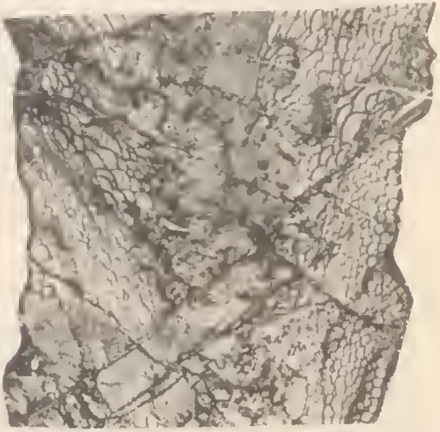

5


6

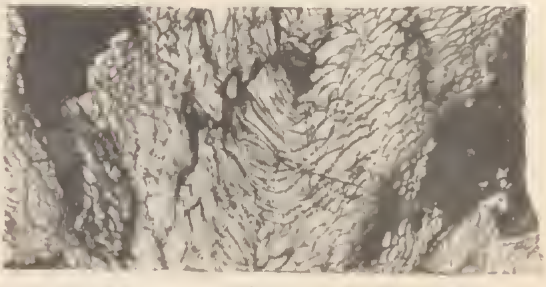

7

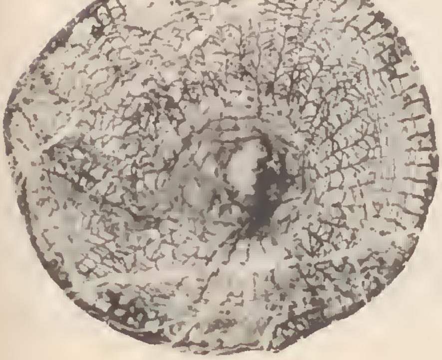

8

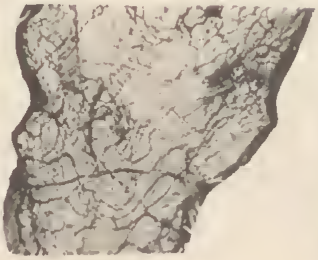

9


10


11

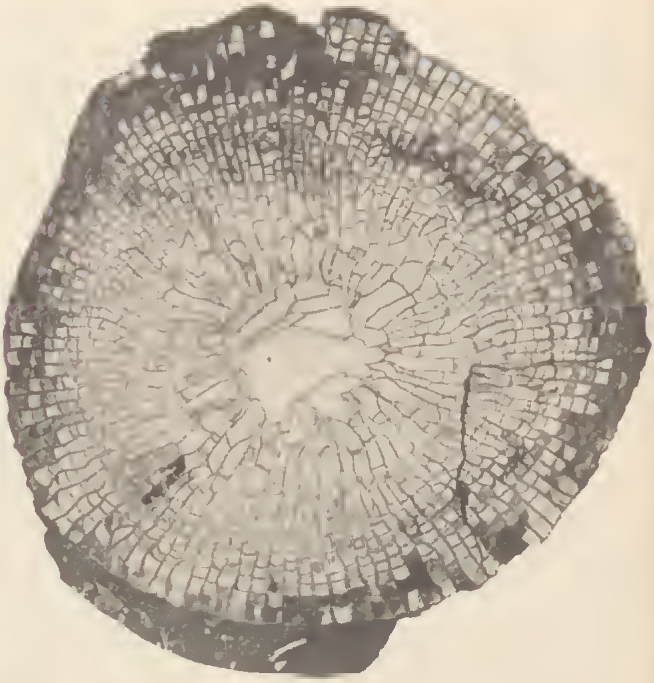

12


13


14

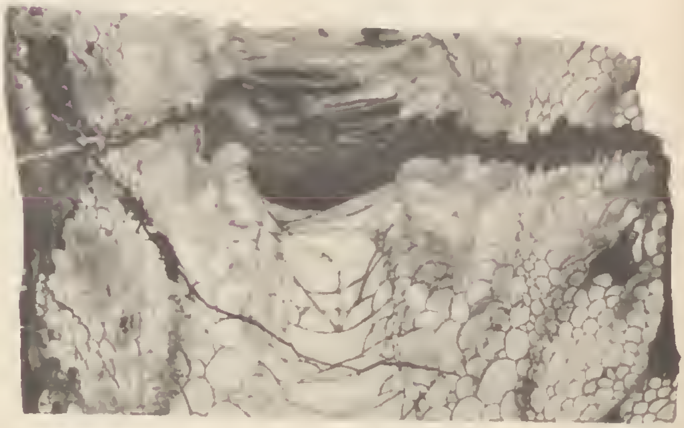

15

1

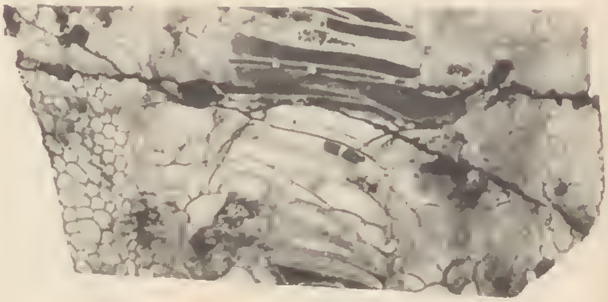


2

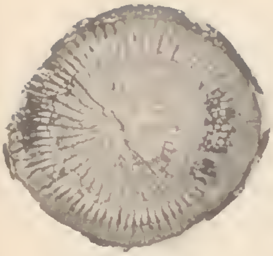
3



4

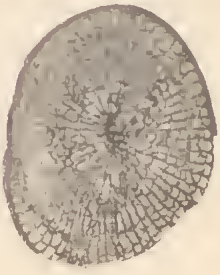


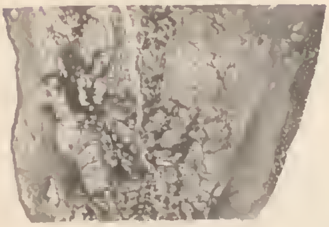
5


1


2

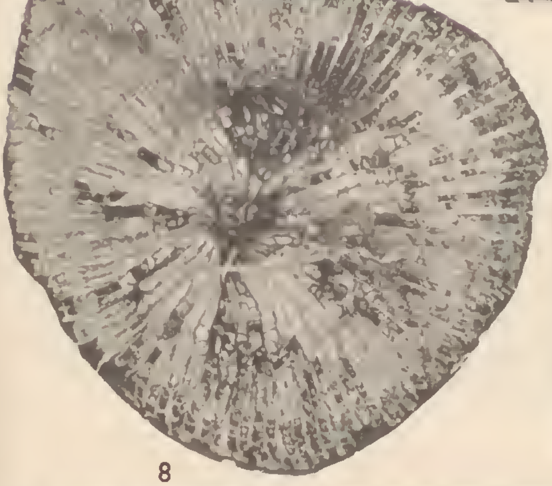

3

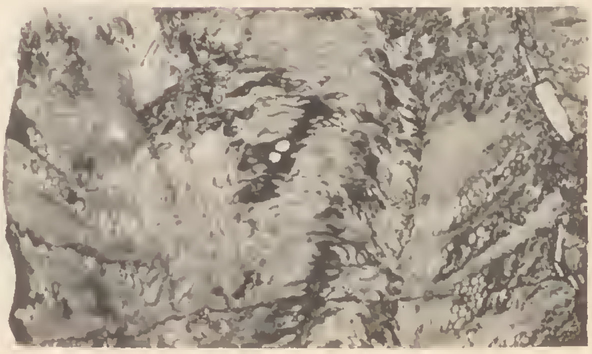

4

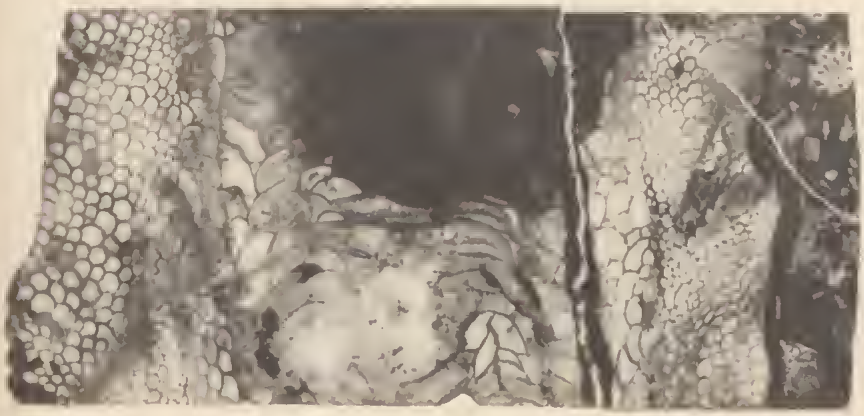

5


6

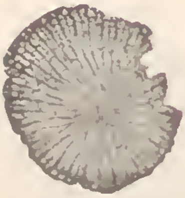

7

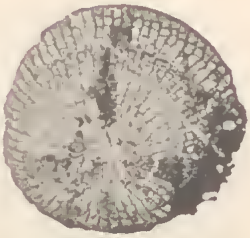

8

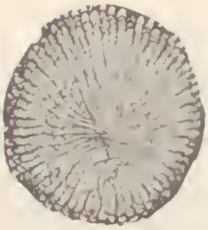

9

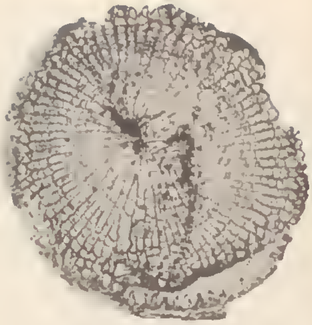

10

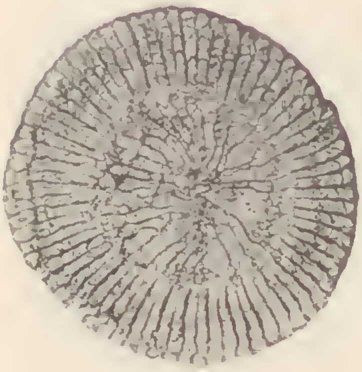

11

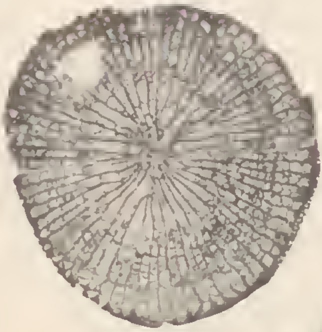

1

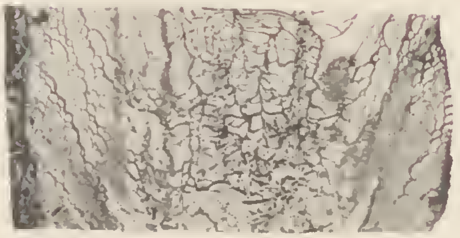

2


3


4

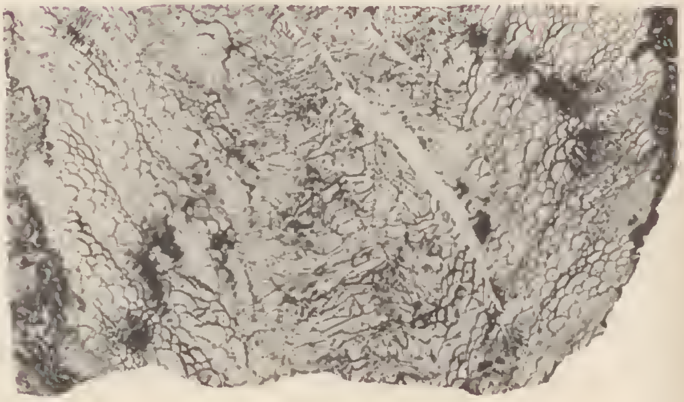

5

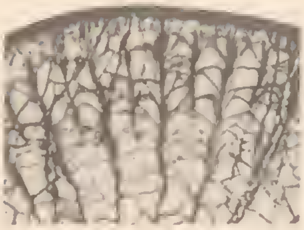

6


7

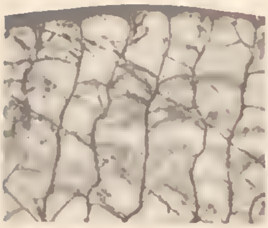

8


9

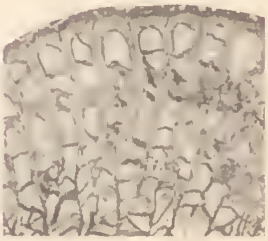

10



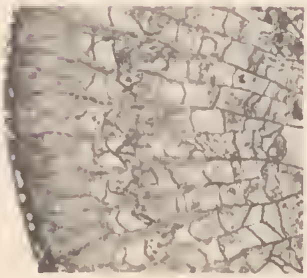
1



2

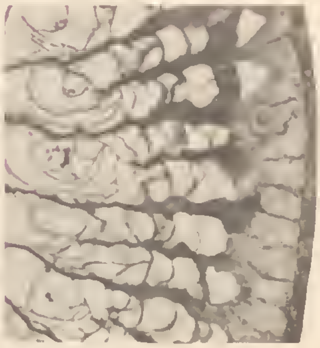


3



4

5

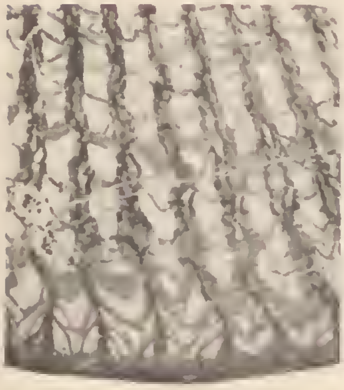


6

7

8

9



10

11

12

16

THE GEOLOGY OF THE UPPER YARRA REGION, CENTRAL VICTORIA

By Bruce R. Moore

Geology Department, University of Melbourne

Abstract

The structure of the Siluro-Devonian sediments of the area is given in detail. The complex domes and basins encountered, resulting from the variable fold plunges, were interpreted in the field by means of the new graphical method described.

The detailed stratigraphy of the region is given and the rock units of the St Clair, Matlock, Tanjil, and Upper Yarra formations are included. The Siluro-Devonian boundary is discussed and, on the basis of recent graptolite determinations by Professor Hermann Jaeger, the strata containing the *Monograptus-Baragwanathia* association are placed in the Devonian, as are the overlying *Panenka-Styliolina* beds.

Turbidity current deposition is indicated, with a constant movement of sediment from the W. The increased frequency of turbidites towards the top of section is attributed to the tectonic movements in the geosyncline in the initial stages of the formation of the Upper Yarra Anticlinorium. The origin of the *Panenka* beds is thought to be related to turbidity currents.

Introduction and Previous Literature

The region mapped in the present survey consists principally of the Siluro-Devonian sediments in the basin of the Upper Yarra. Most of the detailed work was achieved in the vicinity of the Upper Yarra Dam, since the rugged terrain in the E. of the area made detailed mapping extremely difficult.

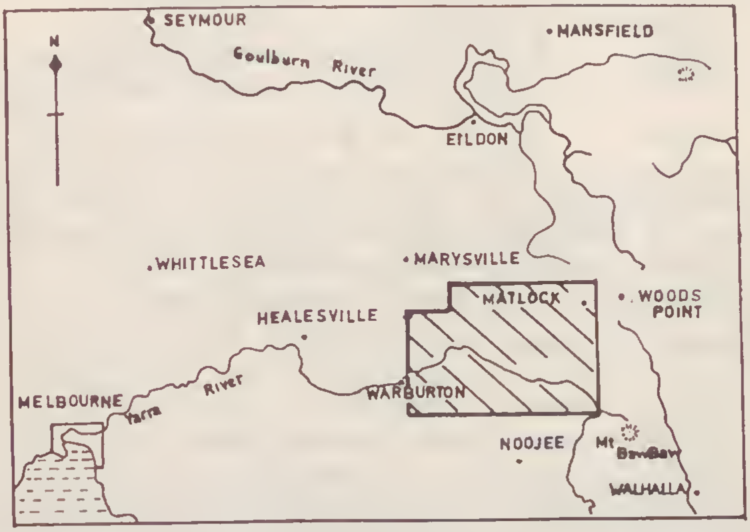


Fig. 1—Area Location.

The earlier mapped igneous boundaries were taken from the work of Hills and of Edwards for the Marysville Igneous Cauldron Subsidences and the Warburton areas respectively. The mapping was extended to the E. to join the work of Harris and Thomas (1947) on the strike faulted boundary between the Ordovician and Silurian sediments at Matlock. Detailed structural interpretation of the area, together with close definition of the rock units and sedimentation, was necessary in view of the unfossiliferous nature of the sediments.

Numerous small reports on the mines of the area constitute the earliest literature. In the first major contribution, Whitelaw determined the stratigraphical sequence of the area, describing the major rock units. It was obvious from his work that the succession E. of the doubly synclinal Walhalla Synclinorium differed markedly from that to the W. Inliers of Upper Ordovician sediments, monoclinal folds, and extensive gold deposits were described.

The Baragwanath memoir (1925) on the Aberfeldy District gave a comprehensive description of the geology of the area S. of that described by Whitelaw. He established that the Tertiary gravels occurring at different levels throughout the area were deposited during uplift and were not the result of uplift. He determind the extension of the basal grits of the Walhalla beds and their relationship to the other coarse grits in the section and described the Baw Baw Granodiorite and its contact zone.

Edwards (1932) described the igneous rocks of the Warburton district and discussed the petrogenesis of the Warburton Granodiorite, related dykes, and the Dacite suite.

Relationships between the Warburton Granodiorite and the Tynong Granite were discussed in a paper by Baker, Gordon, and Rowe (1939). Clear evidence was cited to show that the granite was intrusive into the granodiorite.

The major contributor to the geological knowledge of the area was Thomas (1937-1961), partly in collaboration with Harris. The basic elements of the stratigraphy of the Siluro-Devonian sediments of the East Central Victoria were outlined, the main marker horizons were indicated and an attempt made at correlation. The main subdivisions used by Harris and Thomas were:

Devonian	Lower	Walhalla Beds
	Upper	Tanjilian, including the *Panenka-Styliolina* beds
Silurian	Middle	Melbournian, including the *Monograptus-Baragwanathia* beds
	Lower	Keilorian, including the *Monograptus exiguus* band

The importance of the *Panenka-Styliolina* association was discussed by Gill (1941); he considered some of the *Styliolina* occurrences to be of Yeringian (Lower Devonian) age, and some Upper Silurian. Philip (1960) suggested the top of the Tanjilian be taken as the Siluro-Devonian boundary.

The Marysville Igneous Complex, bounding the NW. corner of the present map, was described by Hills (1956). The existence of the two major cauldrons was explained, together with the mechanism of subsidence relating to the surrounding ring dykes.

Structure

METHOD OF INTERPRETATION OF THE PLUNGING FOLDS

Early in this survey, the author realized the complexity of the outcrop patterns produced by changes of plunge in the many close folds. The normal methods of plunge determination proved to be too slow, and necessitated too many observations for satisfactory use in the field. Since the marker horizons are generally concealed and of small thickness, the mountainous terrain and the changes of plunge made their outcrops difficult to trace.

The author (1964 MS.) has described a graphical method of rapid plunge determination and predicting the outcrop of such beds in the field. The method was developed by isolating a mathematical function, relating the normal field measurements of dip, strike, and plunge of the strata. The deviation in strike of the strata on the two limbs of the plunging fold was expressed as one half of the angle between the two strikes. This deviation was found to be related to the dip and strike of the strata by an arsin function.

A family of curves was plotted for the relationship between the strike deviation for values of dip at 5° intervals. From these curves the plunge of the beds could be very quickly determined by taking the normal measurements of dip and strike. This makes possible the accurate determination of the plunge of a fold even though it may be constantly changing.

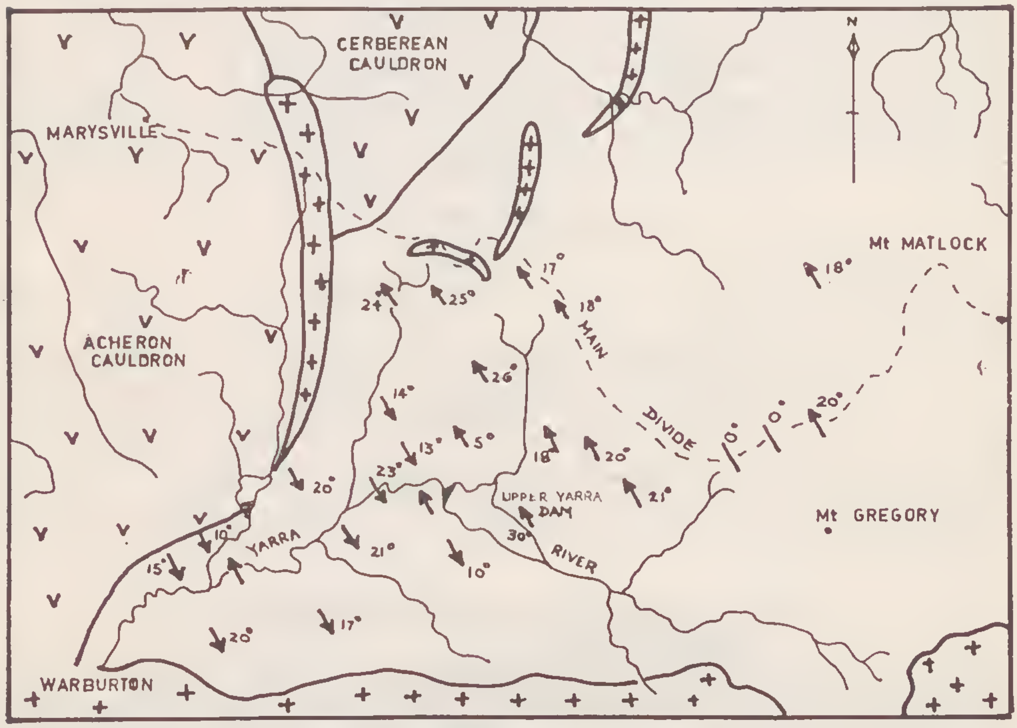


FIG. 2—Analysis of Plunge Directions.

An accurate value of the plunge of the fold is necessary to predict the outcrop of a marker horizon when dealing with severely undulating ground. By the use of the graph of a function relating plunge of the fold, determined by the above method, to the variation in contour height of the two stations, a correction could be applied to theoretical outcrop so that the strata could be located in the field.

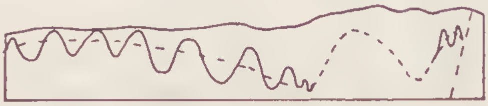
This method was used with complete success in mountainous terrain where outcrops were concealed for considerable distances. In repeated cases, where outcrop was covered for distances of up to 2 miles, the new outcrop could be predicted to within 100 yds.

GENERAL STRUCTURE

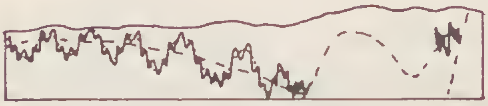
The area is dominated by the Upper Yarra Anticlinorium some 20 miles in breadth, separated from the Walhalla Synclinorium to the E. by several broad simple folds in the vicinity of Matlock. The structures superimposed on this anticlinorium are second order folds consisting of minor anticlinoria and synclinoria with crests from 1-3 miles apart. These folds in turn are composed of third order anticlines and synclines with crests from 50 yds to ½ mile apart.

E. of Monty's Camp, the section is composed of broad anticlines and synclines, which are deep structures containing the greatest thickness of sediments preserved in the area. The major folds axes are shown in Fig. 4. These fold axes of the Monty's Camp Syncline, the Forest Camp Anticline, the Oaks Syncline, and the St Clair Anticline, are spaced at intervals of 3-4 miles; this contrasts with the close fold spacing of the Upper Yarra Anticlinorium.

FIRST ORDER FOLDS



SECOND ORDER FOLDS



THIRD ORDER FOLDS

FIG. 3—Theoretical Folding Analysis.

The limbs of most of the folds in the area have an average dip of 60-70°. The true strike of the sediments varies between N.310 E. and N.340 E., showing a slight convex curve towards the Warburton area. The strong plunges of the folds cause marked deviations from these values in the field, with plunges of 10-35° being common. The resulting outcrops of the domes and basins produce a zig zag pattern of outcrop in the closely folded regions.

The fold pattern of the Upper Yarra Anticlinorium causes repetition of the fossiliferous horizons of the Tanjil Formation W. of the Upper Yarra Dam. These outcrops are repeats of the strata to the E. at Matlock and the old 18 Mile Quarry on the Yarra Track.

Thomas (1947) mapped the boundaries of the Silurian and Upper Ordovician as a series of strike faulted contacts. The present survey adjoins the most westerly of these contacts at McAdam's Hill. No evidence was found modifying the maps and sections of Thomas; these have been included in the E. portions of the accompanying map and section.

Details of the Section

Near Warburton, the sediments are concealed by the detrital deposits from the dacite mass to the N. Nevertheless, evidence for the existence of the Warburton Syncline can be seen in road cuttings S. of the Yarra, also on the Donna Buang Road to the N. The Braham's Creek Syncline is the dominant structure in the East Warburton area, causing repetition of the current bedded Upper Yarra Formation, so prominent on the Reefton Spur Road some 10 miles to the E. The Starvation Creek Anticline is flanked by many close folds causing the *Panenka* beds marker horizon to outcrop at the junction of Starvation Ck and the Yarra R. Prominent cleavage has developed in the blue slates close to the fold axis. Both the Braham's Creek Syncline and the Starvation Creek Anticline show well defined plunges of 25° and 16°, respectively, away from the Acheron Dacite Cauldron; the origin of these plunges will be discussed later.

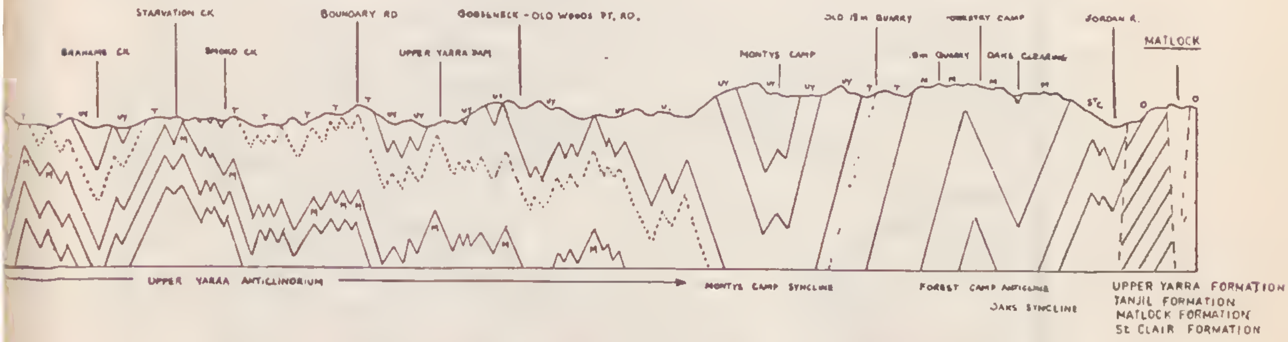


FIG. 4—General Geological Section of the Upper Yarra Region.

A well defined crush zone appears in the section at Reefton, where numerous close repeats of the strata are disclosed. The crush zone lies on a southerly extension of the boundary of the Acheron and Cerberean cauldrons, marked by a prominent ring dyke (Hills 1956). This crush zone marks the point at which the fold plunges change from a southerly direction at East Warburton to a northerly direction at the Upper Yarra Dam. This crush zone possibly reflects bedrock movements associated with the cauldrons. Numerous small folds are present in the section at Muddy Ck, McMahon's Ck, and at Reefton. In this part of the section E. of Reefton, Gill (1942) located a limited horizon with a brachiopod fauna resembling the Yeringian fauna in many respects. This horizon lies immediately above the *Panenka* Beds. There is also a close association of plant remains (including *Hostimella*) with the *Panenka* Beds in this part of the section.

The Yankee Jim Anticline is notable for the reversal of plunge occurring along its axis. On the N. side of the Yarra the plunge is 14-18° to the S., changing to 12° at the Yankee Jim Quarry on the Main Road; farther to the S., on Boundary R, the plunge reverts to 10° S. The complicated outcrop patterns produced by these plunges and reversals will be discussed later.

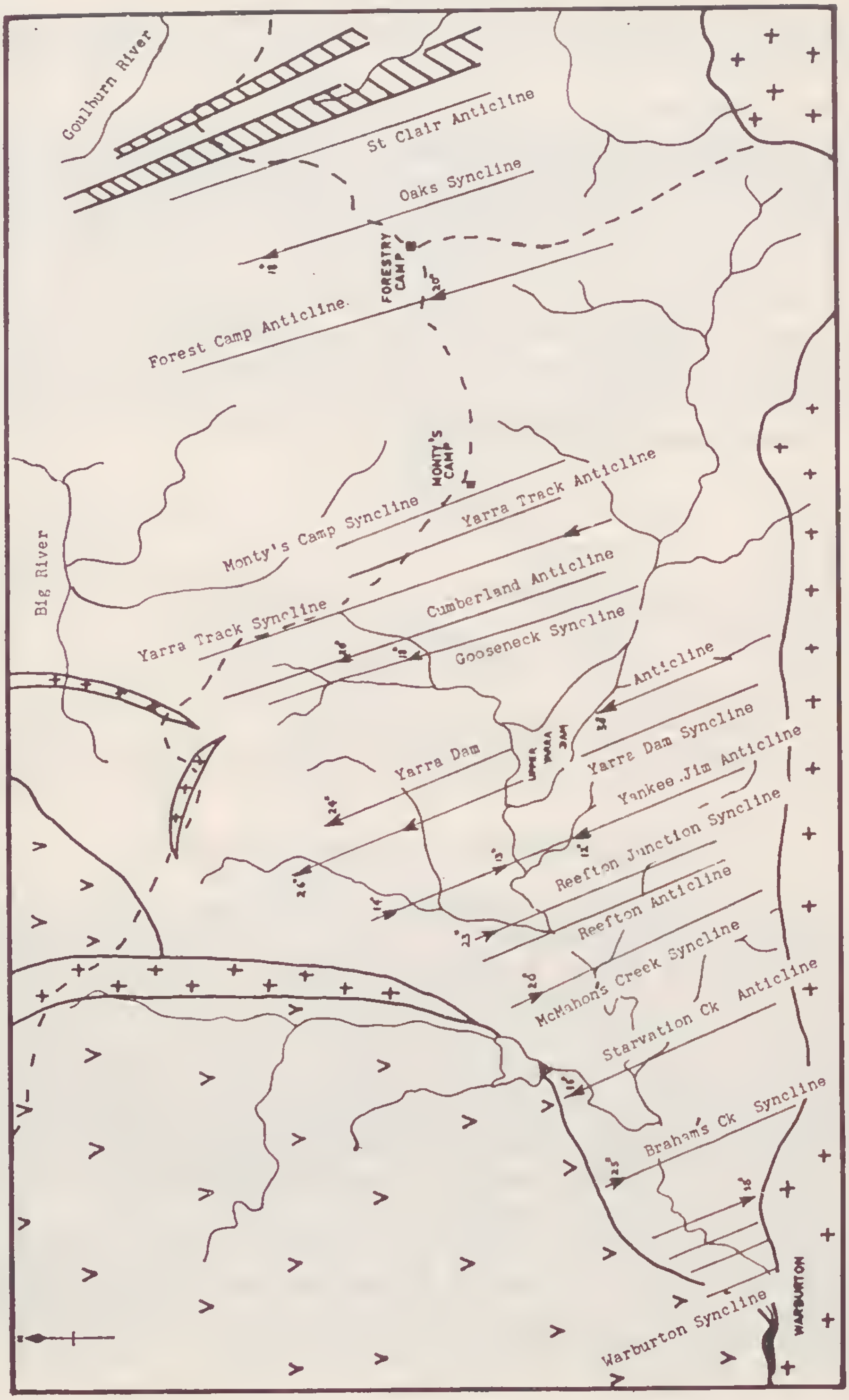


FIG. 5—Major Axial Lines.

E. of the Yankee Jim Anticline, the strata dip to the double synclinal structure of the Upper Yarra Dam itself. The folds terminate in the ring dykes and cauldrons of the Cerberean Cauldron. It is most noticeable that, E. of the large ring dyke marking the margin of the Acheron Cauldron, the plunge of the sediments changes to a northerly direction towards the Cerberean Cauldron. This northerly plunge is maintained in all the major folds N. and E. of the Upper Yarra Dam.

The Gooseneck Syncline is a prominent feature which extends a considerable distance along the strike of the sediments. The structure is seen in the vicinity of the Gooseneck on the Old Woods Point Rd. It is seen again on the new Board of Works access road from the Walsh's Ck Arm of the Dam to the Yarra Track. The structure continues N. to outcrop on the Yarra Track near Cumberland Junction. The plunge of the fold is 23° N. at the Gooseneck, then 18° N. on the Walsh's Ck Rd and 21° N. at the intersection of the fold with the Yarra Track.

E. of the Cumberland Anticline greater thicknesses of Devonian sediment appear in the section, as the Upper Yarra Anticlinorium dips E. towards the Monty's Camp Syncline. The Cumberland Anticline has minor folds on both its flanks, being separated from the large Monty's Camp Syncline by the smaller Yarra Track Syncline and Anticline. These folds can be seen on the Yarra Track but their southerly extension to the Old Woods Point Rd is obscured by soil.

The Monty's Camp Syncline, possibly the most important structure in the section, is over 5 miles in width, and contains the greatest development of sediment in the area. The youngest Devonian sediments are exposd at Monty's Camp itself; between this point and the Forest Camp Anticline almost all the Upper Yarra, Tanjil, and Matlock formations are exposed. Outcrops of the limbs of this fold are discontinuous, but available exposures show it to be of simple form, with dips of 60-70°, giving a total thickness of 18,000 ft of sediment.

Due to lack of exposures, the exact position of the axis of the Forest Camp Anticline is difficult to ascertain on the Yarra Track. A more accurate idea of the fold is obtained 5 miles to the N. on Frenchman's Track where it plunges N. at 32°; the same fold on the Yarra Track has a plunge of 10° to the N.

It is noticeable that both the major folds of the region, the Monty's Camp Syncline and the Forest Camp Anticline, show less plunge to the S. on the Yarra Track. The former shows no plunge at Monty's Camp itself.

Both the Forest Camp Anticline and the St Clair Anticline to the E. are simple folds. Farther E., numerous small folds are encountered before the contact between Silurian and Upper Ordovician at McAdam's Hill is reached.

In general, it is noticeable that the folds in the E. of the area are very broad and simple, involving a large thickness of sediment. In contrast to this, the folds in the W., comprising the Upper Yarra Anticlinorium, are complex and closely situated. It is considered possible that the intensity of folding in the W. of the area is related to the plutons and volcanic cauldrons. A final conclusion cannot be reached until the current detailed mapping of the bedrock structure to the N. and W. of these cauldrons is completed. Nevertheless, this triangular area of sediments, bounded on the N. and W. by the cauldrons, and on the S. and W. by the plutons, has experienced the most intense folding in this region.

Relation of the Plunge of the Sediments to the Cauldron

It is particularly noticeable that the plunges of the sediments in the vicinity of the Acheron Cauldron are generally in a southerly direction, whereas those close to the adjacent Cerberean Cauldron have a generally northerly trend.

It is also striking that the reversal in plunge of the surrounding sediments occurs at the junction of the two cauldrons. While no direct evidence linking the cauldron mechanism with the plunge of the bedrock was found it is considered that a relationship exists. While the movement of the basement within the confines of the cauldron would be vertically downwards, the bedrock outside the cauldrons could have been buckled in opposite directions giving the different plunges observed.

RELATION OF THE STRUCTURE TO THE WOODS POINT DYKE SWARM

This dyke swarm is of late Middle Devonian and early Upper Devonian age. It is made up of hundreds of acid dykes, stretching from Walhalla NW. of Eildon (Hills 1952). The present area, to the W. of the main swarm, had not been examined for dykes and an exhaustive search during the present survey revealed only a few small dykes, but no lateral extension of the swarm.

It is now clear that the dykes are confined to the belt of sediments E. of the line of the Baw Baw pluton and the Cerberean Cauldron. Some dykes were recorded S. of the Tynong Granite in the region of the Tanjil R. by Hills. These dykes were not found to continue N. of the granite into the present area. The strong lineation of the dykes closely follows the strike of the sediments in which they occupy fractures.

MECHANISM OF THE FOLDING

The exact stages in the formation of the folded structures in the area are difficult to reconstruct. A mechanism which would produce such persistent close folding in the W. of the area and broad open folding in the E. is unusual.

All major folds and many of the minor folds in the area show a remarkable persistence along strike and can be traced along their axes for distances of 10-15 miles. The angles of dip remain approximately constant but the plunges change frequently. Folds E. of the Upper Yarra Dam tend to show an arc-like sweep, convex towards Warburton.

A study of the sedimentation shows a constant westerly source direction for the Tanjil Formation and the overlying Upper Yarra Formation. The thickness of both these formations is less in the Warburton area than in the vicinity of Matlock. The sudden introduction of large scale turbidite sedimentation towards the top of the Tanjil Formation is interpreted as heralding the commencement of fold movements.

These first movements could have involved arching on the site of the Upper Yarra Anticlinorium. If this region began to rise before the Matlock region, this would explain the apparent resorting of sediment towards the E. in the Upper Yarra Formation. This is supported by further work to the W. of Warburton on the W. flank of the Upper Yarra Anticlinorium where sediment of a similar age to the above has moved in the opposite direction. This concept would imply a sea floor slope away from the axis of the Anticlinorium and a consequent gentle unconformity or offlap from bed to bed. Such a structure would be almost impossible to trace in the field without continuous outcrop of a particular bed.

A turbidite origin is suggested to account for the current-bedded structures in the Upper Yarra Formation but until further investigations are concluded it is not considered to be conclusive. The existence of a bottom slope at the time of deposition of the Upper Yarra Formation is indicated by directional studies on the sediment.

The earth movements were probably slow and continuous to the Middle and Upper Devonian and no pulsations of sedimentation are indicated. The final stage was the earth movement associated with the ring dykes and cauldrons.

Stratigraphy

This study is made difficult throughout the area by the scarcity of fossils, and hence the lack of accurate marker beds. The original marker horizons used by Harris and Thomas in mapping neighbouring areas were found to apply with certain modifications.

The problem of the boundary between the Silurian and the Devonian has long been recognized as difficult in this area due to the lack of zone fossils. Harris and Thomas took the well-defined basal conglomerates and grits of the Walhalla Synclinorium as the base of the Walhalla Beds and took this as a convenient horizon to mark the base of the Lower Devonian. These conglomerates and grits are not present in the Warburton-Matlock area. Philip (1962) considers the basal conglomerates, limestones, and grits of the Walhalla Group in the Tyers R. area to be early Lower Devonian in age.

In the present area, in the absence of a suitable marker horizon, a formation of black slates 1500 ft above the *Panenka* Beds was taken to be equivalent to the Basal Grits of the Walhalla Group known to outcrop E. of the present area. This formation of black slates is clearly exposed 2 miles E. of Monty's Camp. It repeats again on the Old Woods Point Rd in the vicinity of the Gooseneck, to the W. of the Upper Yarra Dam on Boundary Rd, and again in the W. of the area in the Braham's Creek Syncline.

Whether or not this black slate formation at the top of the Tanjil Formation approximates the Siluro-Devonian Boundary will depend on more accurate determinations of the graptolites from within the Tanjil Formation. Specimens from the well known localities within this formation are at present under review.

The major formations in the Warburton-Matlock area are described below, and a tentative correlation table is given.

THE ST. CLAIR FORMATION

These are the oldest Silurian sediments and outcrop adjacent to the strike fault W. of McAdam's Hill where they are typically represented by black slates. Thomas (1947) showed a *Monograptus exiguus* band in a sketch section of the area. In the present survey this band could not be located; no faunal list or locality was given by Thomas. I have taken the uppermost beds of the St Clair Formation to be the top of the black slates in this area, and the lower portion of the formation at least to be of Keilorian (Lower Silurian) age.

The St Clair Formation is represented by 2000 ft of black slates before the Upper Ordovician of McAdam's Hill is encountered, the uppermost beds of the formation being 4000 ft below the main *Monograptus-Baragwanathia* beds.

THE MATLOCK FORMATION

The Matlock Formation is here defined as including all the strata overlying the uppermost black slates of the St Clair Formation, upwards in the Woods Point Rd Section at Matlock to its own Unit 3, the Oaks Grit. This formation thus includes the strata formerly called the *Monograptus-Baragwanathia* Beds by Harris and Thomas and totals 5000 ft in thickness.

UNIT 1

The basal unit of the Matlock Formation consists of 3000 ft of unfossiliferous sediments, overlying the uppermost black slates of the St Clair Formation. Bluish slates are prominent in the lower beds, together with blue-yellow claystones and greenish siltstones which increase towards the top of the unit. The uppermost beds

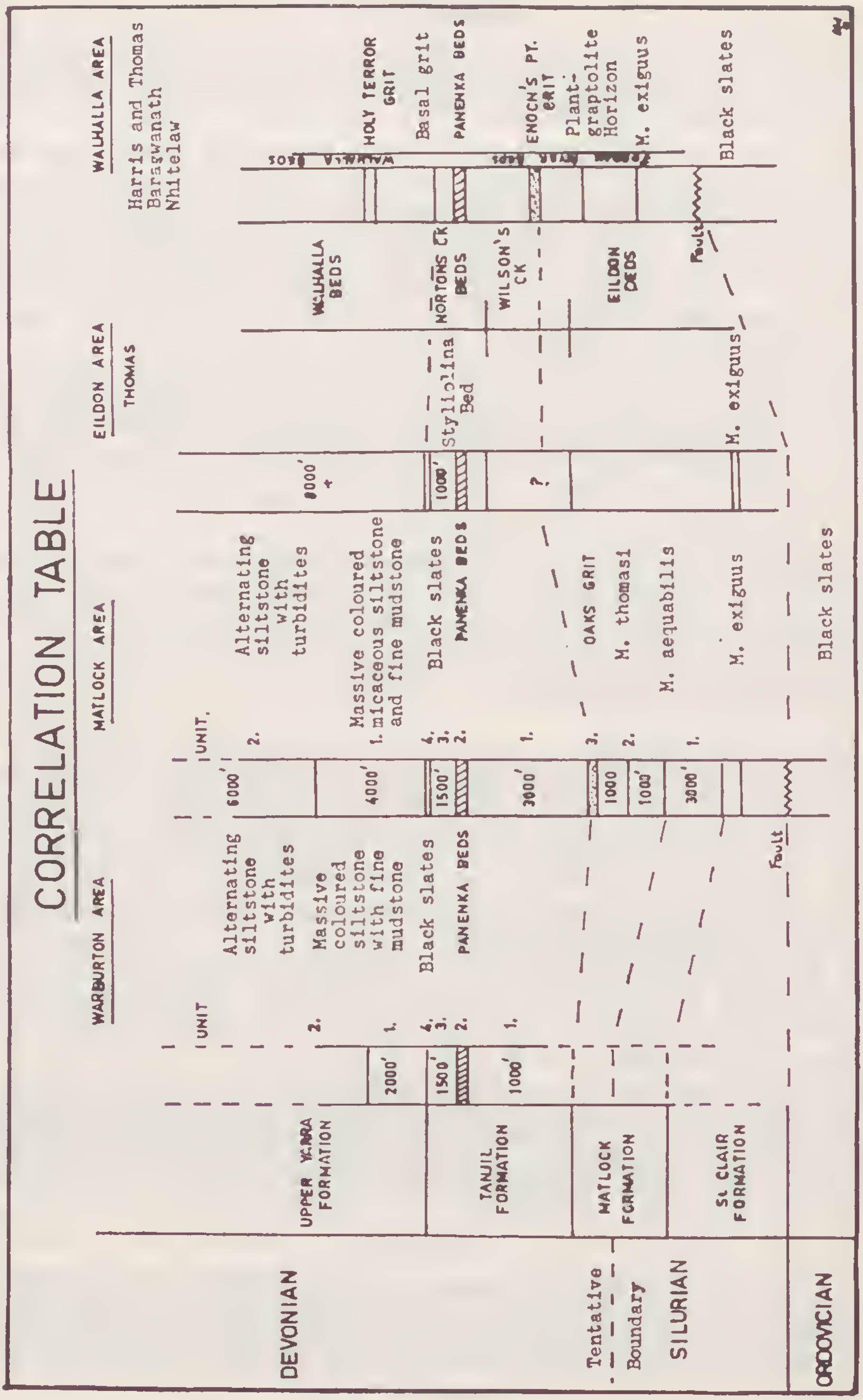

CORRELATION TABLE
DEVONIAN
Tentative Boundary
SILURIAN
ORDOVICIAN
UPPER YARRA FORMATION
TANJIL FORMATION
MATLOCK FORMATION
St. CLAIR FORMATION
WARBURTON AREA
UNIT
2000'
1500'
1000'
2.
1.
4.
3.
2.
1.
Alternating siltstone with turbidites
Massive coloured siltstone with fine mudstone
Black slates
PANENKA BEDS
Fault
MATLOCK AREA
UNIT.
6000'
4000'
1500'
3000'
1000
1000'
3000'
2.
1.
4.
3.
2.
1.
3.
2.
1.
Alternating siltstone with turbidites
Massive coloured micaceous siltstone and fine mudstone
Black slates
PANENKA BEDS
OAKS GRIT
M. thomasi
M. aequabilis
M. exiguus
Black slates
EILDON AREA
THOMAS
8000' +
1000'
?
Styliolina Bed
M. exiguus
WALHALLA BEDS
NORTONS CK BEDS
WILSON'S CK
EILDON BEDS
Fault
WALHALLA AREA
Harris and Thomas
Baragwanath
Whitelaw
WALHALLA BEDS
HOLY TERROR GRIT
Basal grit
PANENKA BEDS
EILDON BEDS
ENOCH'S PT. GRIT
Plant-graptolite Horizon
M. exiguus
Black slates

FIG. 6.

of the unit are exposed only to the W. of the Oaks Clearing. Yellowish micaceous siltstones are prominent in the neighbourhood of the clearing itself, but exposures are incomplete and the exact sequence is difficult to determine.

Unit 2

The base of this unit is marked by the incoming of *Monograptus aequabilis* (Pribyl) formerly identified as *Monograptus vomerinus*. This unit is 2000 ft thick and is overlain by the Oaks Grit. The shales of this portion of the unit commence to outcrop in the vicinity of the old 20 mile Quarry on the Woods Point Rd, and they extend westwards to the old 19 mile Quarry. At this locality the former are overlain by strata containing *Monograptus thomasi* Jaeger, formerly identified as *Monograptus uncinatus* together with *Baragwanathia* plants and formerly known as the *Monograptus-Baragwanthia* beds. As far as could be ascertained *Baragwanathia* does not occur in Unit 1.

The rocks of this age originally attracted world-wide interest when *Monograptus* and *Baragwanathia* specimens were discovered on the same slab of rock. At this time, they were thought to be of Middle Silurian age, but recent determinations of the graptolites accompanying the plants and those at the old 20 mile Quarry indicate a Lower Devonian age for the plants. In the recent survey of this area the *Baragwanathia* plants were not found below the base of Unit 2 or above the Oaks Grit, Unit 3 of the Matlock Formation.

Unfortunately the exposures of fossiliferous strata within this Unit 2 have been largely destroyed in recent roadmaking works in the area.

Unit 3 (Oaks Grit)

The uppermost unit of the Matlock Formation is the Oaks Grit, 50-100 ft in thickness. It outcrops in a shallow road cutting about ½ mile W. of the Oaks Clearing. The member also repeats on the W. limb of the Oaks Syncline, nearly ⅔ mile W. of the Forest Camp, near the site of an old timber mill on the N. side of the Woods Point Rd. The repeat on the W. limb of the Forest Camp Anticline could not be found, but a band of coarse sandstones between the 19 and 20 Mile Quarries could represent a lithofacies change.

This Oaks Grit contains fragmentary corals and brachiopods with numerous calcareous particles and lithic fragments with subangular to subrounded form. This grit could be the same age as that mapped by Thomas (1942) at Enoch's Point to the N. of the present area as the basal grit of the Walhalla Group; there it is underlain by *Monograptus* slates.

Tanjil Formation

These beds are an extension of the Tanjilian series defined by Chapman (1924) when he selected localities at Mt Matlock and on the Tanjil R. in defining the formation. Some confusion later arose when Gill (1941) selected the beds found by Whitelaw on the spur between the B.B. Ck and the Jordan R. as the type area for his Jordanian Series. Harris and Thomas (1942) produced detailed sections which showed that Gill had selected the extension of the same beds as those used by Chapman in his original definition; hence the term Jordanian was rejected.

The Tanjil Formation is here defined to include the original beds of Chapman's Tanjilian Series (the present Unit 2) and extended to all the strata overlying the Oaks Grit of the Matlock Formation and upwards to the top of the black slates of Unit 4 of this Tanjil Formation.

The total thickness is 4500 ft in the Matlock area, while only about 2500 ft is exposed in the Reefton area.

UNIT 1

Overlying the Oaks Grit Member of the Matlock Formation are 3000 ft of unfossiliferous sediments. They consist of highly coloured silstones and fine sandstones in shades of yellow, pink, red, and brown. They are commonly observed in the material turned up by roadworks on the Woods Point Rd between 2·5 and 3·5 miles E. of Monty's Camp. The prominent colours of the rocks and the general predominance of micaceous minerals in the hand specimen makes them distinctive.

UNIT 2

These beds, with their fauna of brachiopods and 'pteropods', have long been recognized as an important marker in the Siluro-Devonian sediments of Victoria. McCoy (1879) and Chapman (1905) gave descriptions of *Panenka* and *Tentaculites* respectively. Gill (1942) gave a comprehensive account of the occurrence of *Styliolina*, both on its own and in association with the above species. These '*Panenka* Beds' form one of the most important marker horizons in the area. They contain *Panenka gippslandica* and *Panenka planicosta* with abundant specimens of *Styliolina fissurella, Nowakia matlockiensis*, and orthoconic nautiloids. The *Panenka* Beds vary from 20-100 ft in thickness and have been proven in this survey to be a most reliable marker.

ORIGIN OF THE *Panenka* BEDS

A detailed study of the plant remains and the *Panenka* and *Styliolina* shells has shown that they usually accompany a marked change in sedimentation. The sediments show a turbidite origin with graded bedding, convolute bedding, lithic fragments, flute casts, and other indications of current deposition. Further, the concentration of these fossils in very large numbers is interpreted as due to a catastrophic event in the sedimentation history of the geosyncline. While the fossils are thought to have a longer time range than the time represented by the thickness of these beds, the fact remains that, for some reason, they were exterminated in enormous numbers at this time.

It is concluded, therefore, that the *Panenka* Beds and associated plant horizons of Unit 2 of the Tanjil Formation were deposited by the action of turbidity currents related to folding in this portion of the geosyncline. It is envisaged that the turbulent, muddy conditions were responsible for exterminating the shelly fossils in large numbers and the turbidity current deposited the shells and plants above the initial graded bed of the deposit, relatively close to the change of sedimentation.

UNIT 3

This unit overlies the *Panenka* Beds and varies from 500-1000 ft in thickness. As with all the other major units, the greater thicknesses occur in the E. of the area, in the Monty's Camp Syncline. The lower 100 ft of the unit contains the beds with localized fragmentary brachiopod faunas listed by Gill (1941). The fossiliferous layers are restricted to the Reefton and Upper Yarra Dam areas, and were thought by Gill to be equivalent to horizons in the Yering Group at Lilydale.

The entire unit is unfossiliferous except for the brachiopod bands, and shows turbidite origin with graded bedding, lithic fragments, and current bedding.

UNIT 4

This unit consists of black slates and streaky blue and white siltstones 100-200 ft thick occurring approximately 1500 ft above the *Panenka* Beds of Unit 2. The author regards this Unit 4 as the equivalent of basal grits and conglomerates of the

Walhalla Synclinorium which are not present in the sections at Matlock or Warburton. These basal grits are now considered to be above the base of the Devonian (cf. addendum in Philip 1962; also recent identification of graptolites from the Matlock Formation, Jaeger MS.).

These black slates outcrop on the Yarra Track, approximately 1½ miles past Monty's Camp. They are seen again in a short outcrop on the Old Woods Point Rd below the Gooseneck. The same horizon reappears on Boundary Rd, SE. of the fire tower turnoff, while a similar rock type occurs in a cutting on the Yarra Dam Rd W. of Braham's Ck Cutting.

WALHALLA GROUP

This group of sediments is well known from the Walhalla Synclinorium to the E. of the present area. The maximum thickness of 10,000 ft is exposed in the Monty's Camp Syncline; the thicknesses appear to be considerably less in the W. at McMahon's Ck where less of the section is preserved.

The Walhalla Group in the Warburton-Matlock area is represented by the Upper Yarra Formation.

UPPER YARRA FORMATION

The Upper Yarra Formation is here defined as including all the strata overlying Unit 4, the Black Slate member of the Tanjil Formation, extending upwards to the top of the Monty's Camp Syncline. These beds are the youngest preserved in the Warburton-Matlock area.

UNIT 1

The greatest thickness (4000 ft) of these sediments is developed on the Upper Yarra Track beyond Monty's Camp, overlying the black slates at the top of the Tanjil Formation. The rock types are predominantly coarse to fine massive siltstones interbedded with occasional fine claystones. The claystones are mostly yellow to grey in colour, while the siltstones are mainly pink with shades of orange to yellow. There is abundant evidence of turbidity current deposition, with flute casts, cross bedding, current bedding, convolute bedding, etc.

The Unit 1 reaches its maximum thickness in the vicinity of Monty's Camp and diminishes towards the W.; in the Braham's Ck region of E. Warburton it is less than 1000 ft thick.

In the E., the top of the formation is marked by a prominent plant (*Hostimella*) band in a quarry on the N. side of the Woods Point Rd, 1½ miles E. of Monty's Camp. The rock is a hard greenish black siltstone. The quarry has been closed as it lies in portion of the Upper Yarra Catchment, but considerable quantities of broken stone still remain.

At Braham's Ck, Reefton Spur Rd, and on the Yarra Track beyond Cumberland Junction, the plant band occurs but is not as prominent. Here the sedimentation changes to the rapidly alternating claystones and siltstones of the overlying Upper Yarra Formation, Unit 2.

UNIT 2

These sediments reach a maximum preserved thickness of 4500 ft at Monty's Camp and between the Cumberland and the Dug Out on the Yarra Track. There is less than 1000 ft of this unit in the Braham's Creek Syncline.

The formation is characterized by rhythmically alternating claystones and siltstones, except in the basal beds of the formation on the E. limb of the Monty's Syncline. Here the siltstones are up to 3 ft thick, whereas the average thickness for both sediments in the other outcrops is of the order of 3-9 in.

Sedimentology

The general evidence from the scanty fossil record of the area is that the Silurian and Devonian strata were the result of deep water deposition.

The older sediments of the St Clair and Matlock Formations in general are evenly bedded and show little or no evidence of the action of turbidity currents as a deposition mechanism. In contrast to this, the overlying sediments of the Tanjil Formation and the Upper Yarra Formation show increasing effects of current deposition towards the top of the section. The sudden appearance of current bedding and directional structures in the strata above Unit 1 of the Tanjil Formation is interpreted as marking the commencement of fold movements in this portion of the Siluro-Devonian geosyncline of Central Victoria.

It is envisaged that, as the fold movements began to take effect, portions of the ocean floor began to tilt and alter in level, resulting in much of the sediment being resorted.

DETAILED SEDIMENT STRUCTURES

Details of the palaeocurrent directions were observed in many parts of the area. These were assessed from the clearly defined structures of cross bedding, current bedding, ripple marks, and other directional structures. In almost all localities in which the direction of sedimentation was assessed, the currents were found to originate in the W. This is interpreted as indicating that the direction of slope of the ocean floor at the time was towards the E. and is attributed to the early stages of formation of the Upper Yarra Anticlinorium, at present occupying the W. half of the section.

Rapid changes of texture are observed in many localities, involving changes from very fine mudstones to coarse sandstones. It is commonly noticed that the mudstone is overlain by a graded sandstone, and that the interface between the two sediments shows the influence of a moving current through structures resembling flow casts. At localities F.7, 8, and 9 on lower Boundary Rd, a dark varve-like shale is abruptly overlain by a streaky bluish white siltstone with plant fossils. Similar examples were collected from other localities. In all these cases there is an abrupt change of grain size, together with a change from varve type bedding in the shale to irregular contorted bedding in the sandstones, passing upward into graded siltstone. Graded siltstones commonly overly very fine mudstones, with mud pellets close to the interface.

Varve-like slates are represented widely in the area, and characteristically occur below the level of the *Panenka* Beds in the Tanjil Formation.

The inclusion of mud pellets in coarser sediments such as siltstone is a fairly common occurrence. These pellets have the composition of dark mudstone and are commonly enclosed in coarse micaceous siltstone showing only vague bedding. The pellets themselves usually have no bedding structures, but occasionally vague contorted bedding is noticed. They vary in shape from elliptical to a disc or saucer shape, and rarely exceed an inch in diameter.

It is concluded that the mud pellets represent blebs of the underlying layer of sediment which have been caught up in a turbidity current by the turbulence and swirling motion of its particles. They have a composition representing that of the finer bed.

Examples of current bedding are noticed at all stratigraphic levels in the section but they are extremely well marked in the Upper Yarra Formation. At lower stratigraphic levels in the Matlock and Tanjil Formations only an occasional layer shows current bedding, but in the youngest Upper Yarra Formation almost every layer shows this structure.

A blotchy or mottled appearance is widespread in the sediments of the Tanjil Formation. It consists of coloured lenses and streaks of white, blue, grey, green, and pink in sediments of the siltstone type. It was originally thought to be a differential weathering or leaching effect, but many of the specimens show a difference in grain size between the different coloured portions. The shape of the blebs and lenses and the difference in the grain size suggest an improper mixing of two sediments rather than the differential weathering of one sediment.

Several noteworthy examples of convolute bedding were recorded. In each case the convolutions were outlined in a white siltstone and the bedding layers were clearly marked by dark blue to black layers, showing folds overturned in one direction. The individual convolutions were up to 2 in. in width and 1 in. in height. Sawn sections of this siltstone from locality S.10 clearly illustrate this structure (Pl. 35).

SIGNIFICANCE OF PALAEOCURRENT DIRECTIONS

The two lowest formations in the stratigraphic column, namely the St Clair and Matlock Formations, show no strong indications of source direction for their material. These formations consist of well sorted sediment showing even bedding and indicating a deep water environment. Furthermore, since there is no positive evidence for a shallow water source for the sediment to the immediate W. of the area, it is concluded that the apparent currents and sediment structures are the result of sediment movement on the E. limb of the Walhalla Anticlinorium during

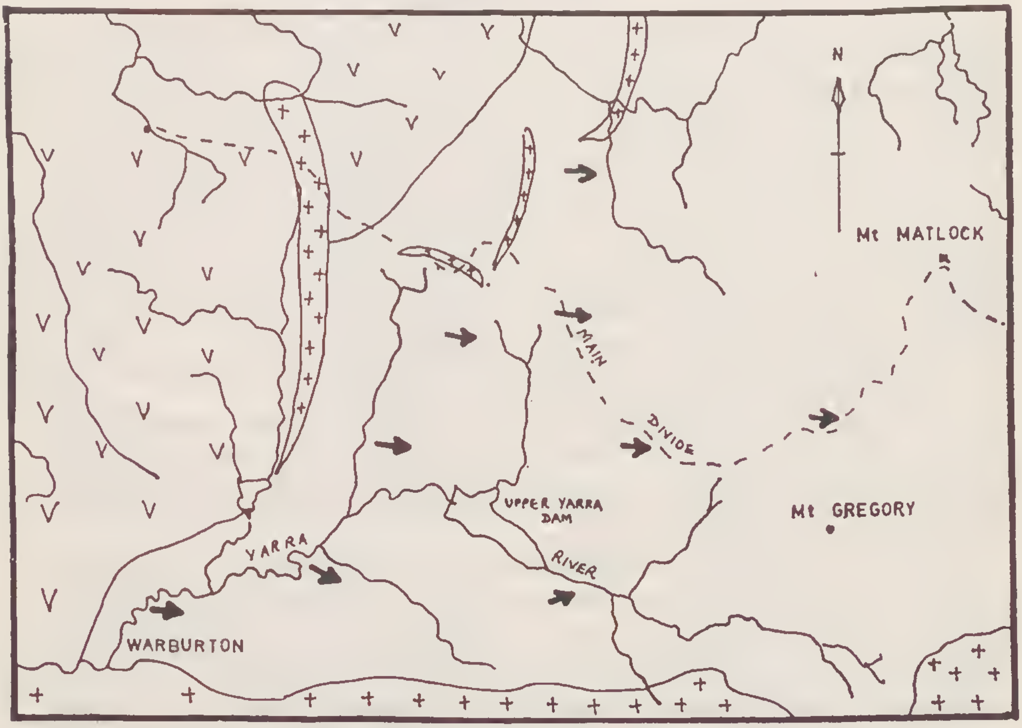


FIG. 7—Palaeocurrent Directions.

its initial stages of formation. The final conclusions will depend on the accurate structure and sedimentation studies at present being conducted in nearby areas.

GENERAL

The sedimentation record for the entire area shows a predominance of fine grained material with only a few medium coarse members. The general conclusion is that the present area represented the deep water portion of the Siluro-Devonian Geosyncline of East-Central Victoria.

The oldest sediment, the St Clair Formation, consists of fine black carbonaceous shales and mudstones of deep water origin, indicating an undisturbed environment. The overlying Matlock Formation has sediments with grain size up to that of medium coarse siltstone with one coarse member, the Oaks Grit.

The general grade of micaceous siltstone is interrupted by a band of dark slates in the Tanjil Formation overlying the Matlock Formation. The material above this, in the overlying Upper Yarra Formation, is of uniform siltstone grade.

There is a dramatic change in the sediment structure with the introduction of a current depositional environment in the upper Tanjil Formation and the overlying Upper Yarra Formation. It has already been recorded that this change is believed to have a tectonic origin and to account for the limited concentrations of otherwise widely distributed fossils such as *Styliolina* and *Hostimella* type plants.

It is doubtful whether all these sediment structures and the distribution of fossil material can be attributed to the action of turbidity current but, pending further investigation, this seems the most likely explanation.

Palaeontology

In the course of the present survey some 70 fossil localities were located and recorded. The location and fossil content of these localities, together with those previously known, are summarized in Table 1. Some of the earlier recorded material was not accompanied by accurate descriptions of the localities and was difficult to trace; other localities were found to be overgrown or destroyed, and these have been marked on the map as close as possible to the original location.

It should be noted that well known localities on the Yarra Track, known formerly as the 18 mile, 19 mile, and 20 mile quarries, have been almost completely destroyed by recent roadworks. The mileages were originally measured from McVeigh's Hotel which is now submerged in the Upper Yarra Dam. It has been established that the Monty's Camp is 15·5 miles from the former site of McVeigh's, along the disused old Woods Point Rd, and mileages were adjusted from this point.

The general unfossiliferous nature of the sediments made correlation difficult, but certain well defined marker horizons could be mapped.

The reliability of the *Panenka-Styliolina* beds, Unit 2 of the Tanjil Formation, was consistently demonstrated in this survey. While the time range of these fossils is known to be much longer than that represented by their occurrence here, it remains that some catastrophe has caused their concentration in this unit, making them a very reliable marker in mapping.

The beds containing the abundant *Hostimella* plant remains are found to be closely associated with the *Panenka-Styliolina* beds and, being considerably thicker, they are a useful guide to the latter. The majority of the *Hostimella* plants were found between the levels of 500 ft above or below the *Panenka* beds. There is one exception—the concentration of these plants in a limited band in the overlying Upper Yarra Formation on the Yarra Track past Monty's Camp.

The band of fragmentary brachiopod material recorded by Gill (1942) near

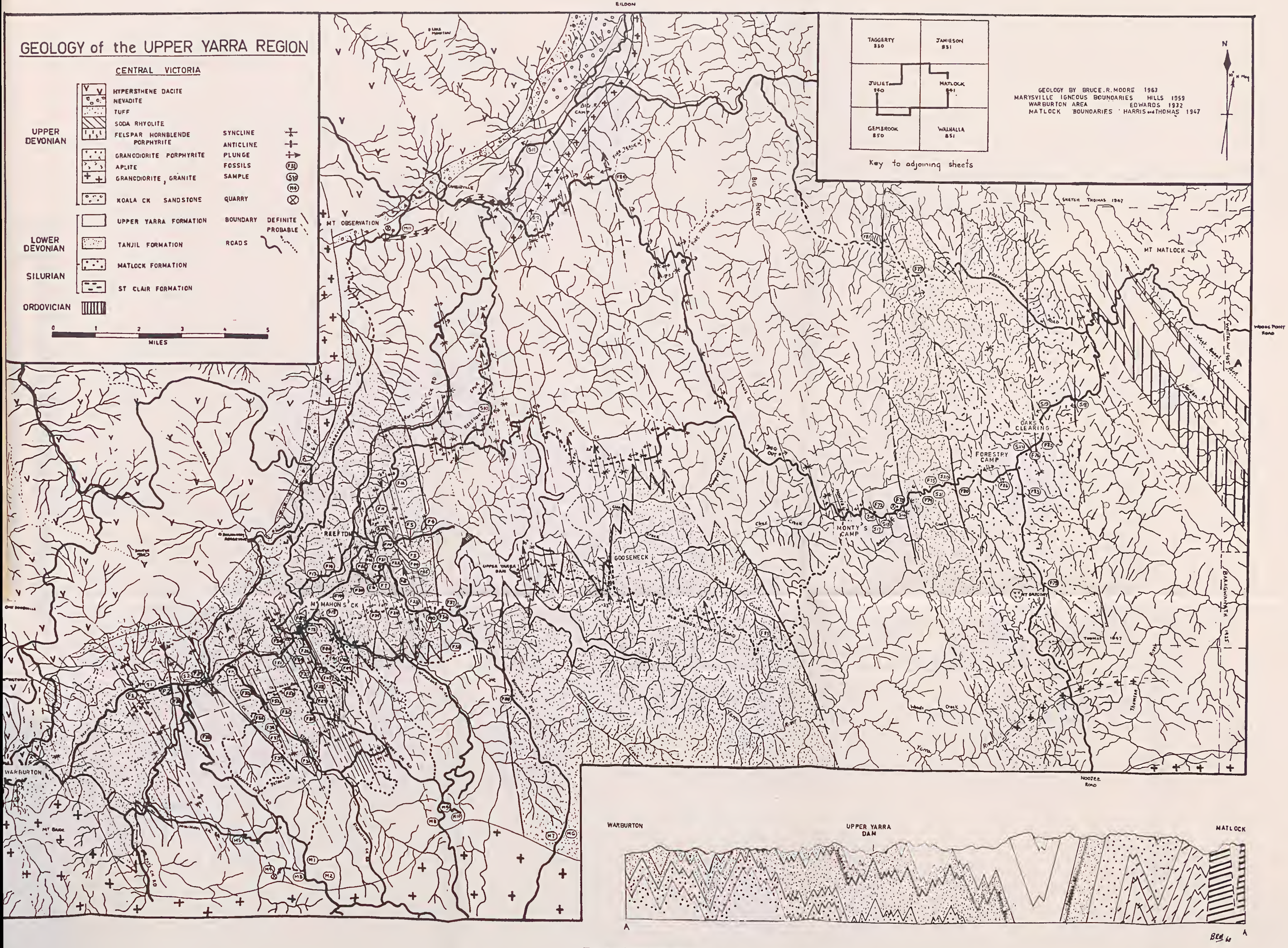


FIG. 8—Geological Map.

TABLE 1

Upper Yarra Fossil Localities

	Main Rd near Braham's Ck Rd	Main Rd near Braham's Ck Rd	Main Rd Quarry Yankee Jim Ck	Drainage Tank Yankee Dam	Main Rd before Yarra Dam	Lower Boundary Rd	Lower Boundary Rd	Lower Boundary Rd	Lower Boundary Rd	Lower Boundary Rd	Reefton Spur Rd	Reefton Spur Rd	Crush Zone Main Rd, Reefton	Aqueduct Yankee Jim Siphon	Armstrong's Ck Rd	Big Bill's Rd off Armstrong's Ck Rd	Aqueduct McMahon's Ck	Aqueduct McMahon's Ck	Aqueduct McMahon's Ck	Lower Boundary Rd	Lower Boundary Rd	Fire Track off Boundary Rd	Fire Track off Boundary Rd	Fire Track of Boundary Rd	Muddy Ck Aqueduct Siphon	Muddy Ck Rd	Muddy Ck Rd	Muddy Ck Rd	Muddy Ck Rd above Trevena's Rd	Starvation Ck Rd	Starvation Ck Rd	Starvation Ck Rd	Main Rd O'Shannassy Turnoff	Braham's Ck Rd	Braham's Ck Rd	Patrol Rd off Starvation Ck Rd	Patrol Rd off Starvation Ck Rd	Patrol Rd off Starvation Ck Rd	Fire Track between Muddy & McMahon's	Fire Track between Muddy & McMahon's	Fire Track before Muddy & McMahon's	Aqueduct before Reefton	Yankee Jim Ck	Yankee Jim Ck	Aqueduct above Reefton	Fire Track off Muddy Ck Rd	Fire Track off Muddy Ck Rd	Fire Track off Muddy Ck Rd	Main Rd near Muddy Ck	Main Rd near Muddy Ck	Trevena's Rd near Starvation Ck Rd	Trevena's Rd	Main Rd before Muddy Ck	Crooked Ck	Boundary Rd before Fire Tower	Boundary Rd before Fire Tower	Fire Track from Boundary Rd	Upper Boundary Rd	Main Rd Starvation Ck Bridge	Woods Pt Rd 1m past Monty's Camp	Woods Pt Rd 1½m. past Monty's Camp	Woods Pt Rd 2½m. past Monty's Camp	Woods Pt Rd Old 18m. Quarry	Clearing 1m. past Forestry Camp	Frenchman's Spur Rd	Main Rd and Muddy Ck Rd	Green Hut Noojee Rd, Mt Gregory	Woods Pt Rd, Old 19m. Quarry	Frenchman's Spur Road	The Oaks Clearing	1m. S. of Forestry Camp	Yarra Track near Fire Track No. 2	5½m. past Gooseneck Old Woods Pt Rd	Old 20m. Quarry	Between Muddy Ck and McMahon's Ck
	F 1	F 2	F 3	F 4	F 5	F 6	F 7	F 8	F 9	F10	F11	F12	F13	F14	F16	F17	F18	F19	F20	F21	F22	F23	F24	F25	F26	F27	F28	F29	F30	F31	F32	F33	F34	F35	F36	F37	F38	F39	F40	F41	F42	F43	F44	F45	F46	F47	F48	F49	F50	F51	F52	F53	F54	F55	F56	F57	F58	F59	F71	F72	F73	F74	F75	F76	F77	F78	F79	F80	F81	F82	F83	F84	F85	F86	F87
ST CLAIR FORMATION																																																																											
Monograptus sp. (cf. *exiquus*)																																																																											
MATLOCK FORMATION																																																																											
Monograptus thomasi																																																																			×			×				
Orthoconic nautiloids																																																																			×						×	
Pterygotus sp.																																																																			×							
Ceratiocaridae indet.																																																																			×							
Baragwanathia longifolia																																																																			×		×				×	
Yarravia oblonga																																																																			×						×	
Monograptus aequabilis																																																																									×	
TANJIL FORMATION																																																																											
Athyris sp.																																																																										×
Atrypa sp.																																																																											
Chonetes n. sp.																																													×																														
Cyrtina sp.																																																																										×
Orbiculoidea sp.																																																																										×
Actinopteria sp.																																																																											
Lunulicardium antistriatum																																																																											
Panenka cinqulata																																																																											
P. gippslandica																																																															×												
P. planicosta								×																		×			×												×	×			×																	×												
P. n. sp.																																																																										×
Paracardium filosum																																																																											
Paracardium ? sp.																																																																											
Posidonomya sp.																																																																										×
Hercynella sp.																																																	×																										
Zygospira sp.																																																	×																										
Coleolus aciculum																																																	×																										
Hyolithes sp.																																																	×																										
Styliolina fissurella					×	×	×																×	×			×			×	×			×								×	×			×		×	×						×				×				×		×	×										
Nowakia matlockiensis					?		?																																																																			
Tentaculites sp.					×												×										×																																×				×												
Orthoconic nautiloids indet.					×		×		×											×	×									×	×									×	×					×			×	×	×								×				×			×									
Ceratiocaris sp.																																																																											
Zosterophyllum australianum			×																																																												×										×		
Hedeia corymbosa																																																															×												
Hostimella sp.		×	×	×						×	×	×	×	×	×		×	×							×		×	×				×	×	×	×	×		×	×					×			×	×					×		×	×	×		×		×	×												
Taeniocrada dechenianus																																												×																											×			
Pachytheca sp.			×																																																																							
Plant remains indet.	×		×					×	×						×	×	×	×	×		×				×	×	×	×	×					×	×		×										×	×				×	×						×	×	×		×			×		×						

Yankee Jim Ck was found to be of limited extent. Mapping showed this band to be of slightly younger age than the *Panenka* beds. Gill considered this brachiopod material to be equivalent to the Yeringian in age.

The most striking result to emerge from the study of these relatively unfossiliferous horizons in the Warburton-Matlock area was the fact that the fossil material is concentrated in well defined bands. It is stressed that in most cases, while the time range of the species extends beyond the bounds of the marked bed itself, the presence of extremely large numbers of organisms in the one bed strongly suggests a turbidity current origin. The structure and sedimentation of strata further suggest a relationship between the turbidites and the tectonic history of the geosyncline.

Igneous Rocks

Igneous activity was widespread at the borders of the Warburton-Matlock area in the Middle and Upper Devonian. Several large plutonic intrusions in the S. are related to the dykes, ring dykes, and cauldron subsidences in the NW. of the area. Hills (1957) concluded that a large magma chamber existed beneath the area.

In the present work the boundaries of the Marysville Igneous Complex were taken from the original field sheets of Hills. The boundaries of the Warburton Granodiorite have been extended to the E. on the present map.

A granitic dyke was mapped to the S. of Mt Gregory where it cuts the Matlock-Noojee Rd. This dyke was traced in very thick timber and appears to be marginal to the main Baw Baw pluton.

METAMORPHIC CONTACT ROCKS

At many localities the metamorphic effects of the large plutonic intrusion were studied. In all cases the metamorphozed zones were relatively narrow, ranging from 10 ft in the case of the dykes to ¼ mile for the large plutons.

The metamorphic zone of the Tynong Granite is seen where the forest roads in the S. of the sheet cross the contact. The Forest Commission has taken stone from numerous small quarries in the upper reaches of Braham's and Muddy Ck Roads. The rock types are generally spotted hornfels and quartz muscovite hornfels with some chiastolite slates.

The Country Roads Board quarry on the flanks of Mt Observation is in hornfels close to the contact of the large granitic ring dyke. This quarry is accessible from the N. end of Observation Rd.

Conclusions

1. The structural analysis of the area shows the majority of the sediments to be of late Silurian and early Devonian age. The older Silurian and the Ordovician sediments previously known from the E. of the area do not outcrop in the W.
2. The value and reliability of the *Panenka* Beds unit of the Tanjil Formation as a marker bed was repeatedly demonstrated.
3. The structural analysis of such a complexly folded area of rugged terrain can be materially aided by the use of a new graphical method of plunge interpretation outlined above. The details are given in Moore (1964 MS.).
4. The possible relationship of the Upper Silurian and Lower Devonian turbidites in the area to the early folding movements was indicated. The relation of both the above features to the origin of the *Panenka* beds and the *Hostimella* type plant beds is also suggested.
5. There is a pressing need for more detailed structural mapping of this nature in the surrounding areas to facilitate a complete interpretation of the sedimentation history of the Melbourne Trough in Central Victoria.

Acknowledgements

This paper is taken from a thesis submitted for the degree of MSc in the University of Melbourne. I am extremely grateful to Professor E. S. Hills for his supervision and guidance, to Dr J. A. Talent and my colleagues at the Geology Department for advice and discussion of the work, and to Professor Hermann Jaeger of Berlin for determinations of graptolites. The CSIRO assisted the project with a grant for which I am indebted and express my thanks. I deeply appreciate the assistance of my wife in the field and in the production of the manuscript.

References

Baker, G., Gordon, A., and Rowe, D., 1939. Granodiorite and granite at Powelltown, Victoria and their relationships. *Proc. Roy. Soc. Vict.* 51.

Baragwanath, W., 1925. The Aberfeldy District of Gippsland. *Memoir 15 Geol. Surv. Vict.*

Chapman, F., 1911. New or little known Victorian fossils in the National Museum. Pt XIII.

————, 1912. New Silurian fossils of Eastern Victoria. Pt II. *Rec. Geol. Surv. Vict.* III: 2.

————, 1913. On the palaeontology of the Victorian Silurian. *Rep. Aust. Ass. Adv. Sci.* XIV.

————, 1926. On the question of the Devonian age of the Tanjilian flora and fauna of Victoria. *Aust. Ass. Adv. Sci.* 17: 313-318.

DeSitter, L. U., 1959. *Structural Geology*. McGraw-Hill.

DeWaard., 1955. The inventory of the minor structures in a simple fold. *Geol. en Mijnbouw* 1: 1-11.

Edwards, A. B., 1932a. The geology and petrology of the Blacks Spur area, Healesville, Victoria. *Proc. Roy. Soc. Vict.* 44: 49-76.

————, 1932b. On the dacite-granodiorite contact relations in the Warburton area. ibid. 44: 163-181.

Gill, E. D., 1940. The Silurian rocks of Melbourne and Lilydale. ibid. 52: 249-261.

————, 1941. The place of the genus *Styliolina* in the Palaeozoic palaeontology and stratigraphy of Victoria. ibid. 53.

————, 1942. The thickness and age of the type Yeringian strata, Lilydale, Victoria. ibid. 54: 21-52.

Harris, W. J., and Thomas, D. E., 1937. Victorian graptolites (new series), Pt IV. *Min. & Geol. Jour. Vict.* 1: 68-79.

————, ————, 1941. Notes on the Silurian rocks of the Yea district. ibid. 2: 302-304.

————, ————, 1942. Notes on the geology of the Enoch's Point District. ibid. 22: 353-360.

————, ————, 1947. Notes on the geology of the Yarra Track area near Mount Matlock. ibid. 3: 44-49.

Hills, E. S., 1940. *Outlines of Structural Geology*. Methuen and Co.

————, 1941. The Silurian rocks of the Studley Park district. *Proc. Roy. Soc. Vict.* 53: 167-191.

————, 1945. Examples of the interpretation of folding. *Jour. Geol.* 53: 47-57.

————, 1952. The Woods Point dyke swarm, Victoria. *Sir Douglas Mawson Ann. Vol. Univ. of Adelaide*: 87-100.

————, 1959. Cauldron subsidences, granitic rocks and crustal fracturing in SE. Aust. *Geol. Rundschau. Band* 47: 543-561.

Hills, E. S., and Thomas, D. E., 1954. Turbidity currents and the graptolitic facies of Victoria. *Jour. Geol. Soc. Aust.* 1: 119-133.

Jutson, J. T., 1911. The structure and general geology of the Warrandyte Goldfield, Victoria. ibid. 23: 516-554.

Kingma, J. T., 1958. The possible significance of graded bedding in geosynclinal sedimentary systems. *Int. Geol. Congress XXI Session.*

Krumbien, W. C., and Pettijohn, F. J., 1938. *Manual of Sedimentary Petrography*. D. Appleton. Century Co., New York.

Krynine, P. P., 1946. The tourmaline group of sediments. *Jour. of Geol.* 54: 65-87.

Kuenan, P. H., 1953. The significant features of graded bedding. *Bull. Am. Ass. Pet. Geol.* 37: 1044-1066.

————, ——. Longitudinal filling of oblong sedimentary basins. *Geol. Inst. Groningen Univ. Publication No. 104* 189-195.

————, 1957. Sole markings on graded greywacke beds. *Jour. Geol.* 65 No. 3: 231-258.

———, 1959. Transport and source of marine sediments. *Geol. en Mijnbouw. Series 21e. Jaargang* 191-196.

Kuenan, P. H., and Migliorini, C. I., 1950. Turbidity currents as the cause of graded bedding. *Jour. Geol.* 58: 91-127.

Lang, W. H., and Cookson, I. C., 1930. Some fossil plants of early Devonian type from the Walhalla Series of Victoria, Australia. *Phil. Trans. Roy. Soc. Lond. Series B* 219: 133-163.

———, ———, 1934. On a flora, including vascular land plants, associated with *Monograptus* in rocks of Silurian age, from Victoria, Australia. ibid. 224: 421-449.

Oepik, A. A., 1953. Lower Silurian fossils from the Illaenus band, Heathcote, Victoria. *Mem. Geol. Surv. Vict. No. 19.*

Packham, G. H., 1960. Sedimentary history of part of the Tasman Geosyncline in SE. Australia. *21st Int. Geol. Congress, Pt XII* 74-83.

Parker, J. M., 1942. Regional jointing in slightly deformed sedimentary rocks. *Bull. Geol. Soc. Am.* 53: 381.

Pettijohn, F. J., 1949. *Sedimentary Rocks.* Harper & Bros, New York.

Phillip, G. M., 1960. Victorian Siluro-Devonian faunas and correlations. *21st Int. Geol. Congress* 143-157.

Skeats, E. W., 1928. Stratigraphical and structural relations of the Silurian rocks of the Walhalla-Woods Point District, Victoria in relation to the Tanjilian series. *Aust. Ass. Adv. Sci. Hobart* 219-230.

Thomas, D. E., 1937. Some notes on the Silurian rocks of the Heathcote area. *Min. & Geol. Jour. Vict.* 1: 64-67.

———, 1939. The structure of Victoria with respect to the Lower Palaeozoic rocks. ibid. 1 No. 4: 59-64.

———, 1947. Geology of the Eildon Dam project. *Mem. Geol. Surv. Vict.* No. 16.

———, 1959. The geological structure of Victoria. *Jour. Roy. Soc. N.S.W.* 92: 182-190.

———, 1961. Mineralization and its relation to the structure of Australian ore deposits. *Vict. Year Book* 75: 42.

Weller, J. M., 1960. *Stratigraphic Principles and Practice.* Harpers Geoscience Series.

Williams, G. E., 1964. Geology of the Kinglake District, Central Vict. *Proc. Roy. Soc. Vict.* 77: 273-327.

Whitelaw, O. A. L., 1916. The topography, geology and mines of the Woods Point District. *Geol. Surv. Vict. Memoir* 13.

Explanation of Plate

Plate 35

Fig. 1—A general view of the terrain surrounding the Upper Yarra Dam in the centre of the surveyed region.

Fig. 2—Ripple marked siltstones of the Tanjil Formation at the Upper Yarra Dam.

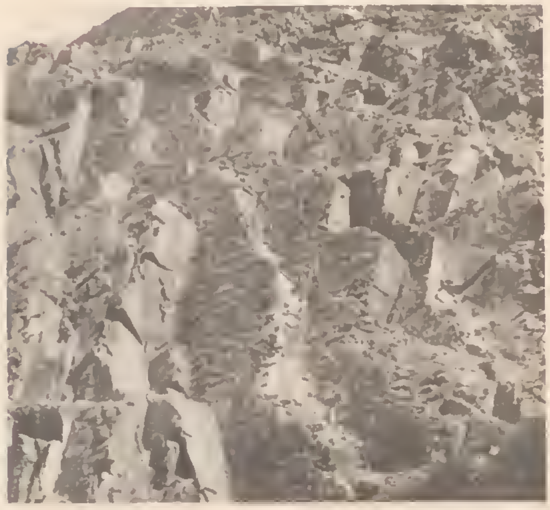
Fig. 3—Plants of the *Hostimella* type, × 1.

Fig. 4—*Baragwanthia* land plant associated with *Monograptus* n. sp. from the Yarra Track, × 1.

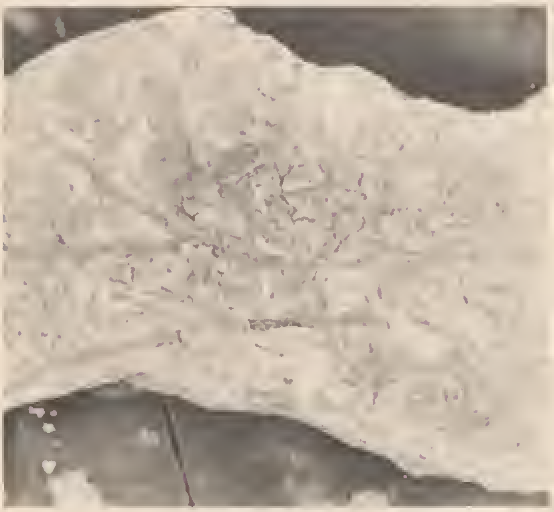
Fig. 5—An example of convolute bedding from locality S.10, × 1.

Fig. 6—A turbidite interface between mudstone and the overlying graded, current bedded siltstone, × 2.

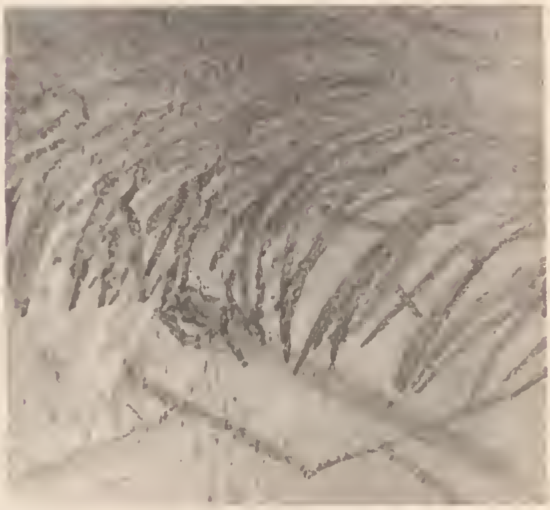
1



2

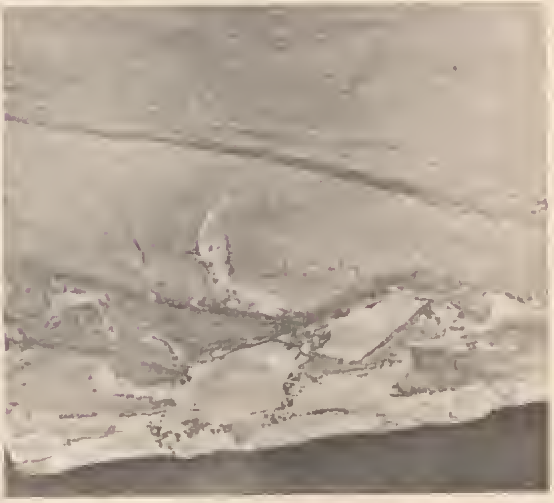


3



4

5



6

Royal Society of Victoria

1965

Patron:

His Excellency Major-General Sir Rohan Delacombe, KCMG KBE CB DSO

President:

J. H. Chinner, BSc, DipFor

Vice-Presidents:

Assoc. Prof. C. M. Tattam, PhD DSc
P. G. Law, CBE, DAppSc MSc, FAIP

Hon. Treasurer:

L. Adams

Hon. Librarian:

Assoc. Prof. C. M. Tattam, PhD DSc

Hon. Secretary:

E. D. Gill, BA BD, FGS FRGS

Hon. Asst Secretary:

D. Spencer-Jones, BSc PhD

Council:

Above Officers with—

V. G. Anderson, FRIC
Prof. J. Andrews, MA PhD *Cantab*
W. Baragwanath, OBE
H. C. Chipman, ISO, LLB
B. D. Cuming, PhD *Cantab*
R. R. Garran, MSc PhD, FRACI
Prof. G. W. Leeper, MSc
J. D. Morrison, PhD DSc, FAA
R. T. M. Pescott, MAgrSc, FRES MIBiol
C. E. Resch, BSc PhD
Prof. G. C. Schofield, MD DPhil
Prof. J. S. Turner, MA PhD MSc, FAA

COMMITTEES OF THE COUNCIL

Publication Committee:

The President
The Hon. Treasurer
The Hon. Secretary
The Hon. Editor
The Hon. Asst Secretary

House Committee:

The President
The Hon. Treasurer
The Hon. Secretary
The Hon. Asst Secretary
Prof. J. S. Turner, MA PhD MSc, FAA

Development Committee:

The President
The Hon. Treasurer
The Hon. Secretary
The Hon. Asst Secretary
C. E. Resch, BSc PhD
G. E. Fethers, BVSc
R. R. Garran, MSc PhD, FRACI
Prof. E. S. Hills, DSc PhD, FRS FAA

Library Committee:

The President
Prof. G. W. Leeper, MSc
The Hon. Librarian
The Hon. Secretary
The Hon. Asst Secretary

Hon. Editor:

Prof. G. W. Leeper, MSc

Hon. Architect:

R. Grounds, BArch, FRAIA FRVIA

Hon. Financial Adviser:

W. I. Potter, BEc

Hon. Solicitors:

Phillips, Fox & Masel

Hon. Auditors:

R. R. Garran, MSc PhD, FRACI
D. A. Casey, MC, FSA

Trustees:

Prof Sir Samuel M. Wadham, MA LLD, AgrDip
A. R. L. Wiltshire, CMG DSO MC VD
The Hon. Sir Arthur Dean, LLM
Prof. E. S. Hills, DSc PhD, FRS FAA

1965

LIST OF MEMBERS AND ASSOCIATES

WITH THEIR YEAR OF JOINING

[Members and Associates are requested to send immediate notice of any change of address to the Honorary Secretary]

HONORARY MEMBERS

Menzies, Right Hon. Sir Robert G., KT CH QC, LLM, FAA, Prime Minister's Lodge Canberra, ACT	1958
The Right Hon. The Lord Casey, PC CH, DSO MC, 73 St James St, London, SW1	1961
Brooks, General Sir Dallas, KSB KCMG KCVO DSO KStJ, Golf Links Rd, Frankston	1963

LIFE MEMBERS

Anderson, V. G., FRIC, 360 Collins St, Melbourne, C1	1943
Bage, Miss F., OBE, MSc, Grove Cr., Toowong, Brisbane, SW1, Q.	1906
Baker, G., DSc, CSIRO Mineragraphic Investigations, University, Parkville, N2	1935
Balfour, L. J., BA MB BS, 62 Hopetoun Rd, Toorak, SE2	1892
Baragwanath, W., OBE, 327 Orrong Rd, E. St Kilda, S2	1922
Bonython, C. W., BSc, Romalo House, Romalo Av., Magill, S.A.	1945
Brumwell, C. S., 26 Burridge Leith Court, RSL Village, Cheltenham, S22	1946
Butement, W. A. S., CBE, DSc, MIEE FInstP, 5a Barry St, Kew, E4	1955
Colliver, F. S., Geology Dept, University of Queensland, St Lucia, Q.	1933
Cookson, I. C., DSc, Botany Dept, University, Parkville, N2	1919
Finch, L., BArch PhD, 27 Hawdon St, Heidelberg, N22	1955
Honman, C. S., BME MSc, 3 Pevensey St, E. Geelong	1934
Lewis, J. M., DDSc, 'Little Croft', Winterly Av., Point Lonsdale	1921
Miller, L. F., 'Moonga', 23 Power Av., Toorak, SE2	1920
Osborne, Prof. W. A., MB BCh DSc, 'The Hall', Kangaroo Ground	1910
Prentice, H. J., BA BSc, ADipFor (*Cres*), Strangways	1936
Reid, J. S., 'Green Hedges', Somers	1920
Rogers, J. S., MC, BA DSc, 7 Carn Av., Ivanhoe, N21	1924
Sayce, E. L., BSc, FInstP, 16 Maleela Av., Balwyn, E8	1924
Stach, L. W., MSc, 255 Beaconsfield Pde, Middle Park, SC6	1932
Withers, R. B., MSc, DipEd, Food Preservation Research Laboratories, Private Bag, Homebush, N.S.W.	1926

MEMBERS

Adam, W., DDSc, Moorakyne Av., Malvern, SE4	1958
Adams, L., 751 Canterbury Rd, Surrey Hills, E10	1946
Aitchison, G. D., ME PhD, 17 Boronia St, Vermont	1959
Aitken, Yvonne, MAgrSc, Agriculture Dept, University, Parkville, N2	1936
Alexander, G. N., Bayview Rd, Belgrave	1951
Anderson, C. G., MMechE, Rosa St, Lower Templestowe	1957
Anderson, G., MA LLM MCom LittD, 54 Winton Rd, Ashburton, SE11	1924
Andrews, Prof. J., MA PhD *Cantab*, Geography Dept, University, Parkville, N2	1963
Ashton, D. H., BSc PhD, Botany Dept, University, Parkville, N2	1949
Atkins, Christine M., BA MB BS, 14 Wave St, Hampton, S7	1964
Atkins, G. A., MA MSc, 137 Doncaster Rd, N. Balwyn, E9	1959
Attiwill, P. M., BSc, DipFor, 54 Fitzgibbon St, Parkville, N2	1960
Austin, C., 'Willaroo', Casterton	1959
Bachelard, E. P., BScF PhD, AMIFA, Flat 9, 5 Scott St, Elwood, S3	1963
Bain, A. D. N., DSc, FGS, 'Seafell', Narrung Rd, Mt Eliza	1950
Backhouse, R. A., BSc, DipEd, 246 Domain Rd, South Yarra, SE1	1962
Barker, H. E. R., BSc, PhC FPS FRACI, 4 Hillcrest Av., Kew, E4	1957
Barrett, A. O., 'Adderbury', 17 Sorrett Av., Malvern, SE4	1908
Bartlett, A. H., BSc, 38 Kent Av., Croydon	1952
Bartram, R. D., MC, BA MB BS, 222 Canterbury Rd, Canterbury, E7	1958
Bassett, Sir Walter E., MC, MMechE BEE, 133 Kooyong Rd, Armadale, SE2	1957
Bate, O. E., BScEng, Thoneman's Rd, Hoddle's Creek	1954

Beadnell, L. M. M., MRCS LRCP FRGS, 23 Anderson St, E. Malvern, SE5	1959
Beasley, A. W., MSc PhD, DIC FGS, National Museum of Victoria, Russell St, Melbourne, C1	1950
Beavis, F. C., BSc PhD, Geology Dept, University, Parkville, N2	1957
Bell, K., BSc, 45 Waitara Gr., Norlane	1961
Benedek, S., B(geol.) *Budapest*, 2 Hill Top Cr., E. Burwood	1963
Bentley, G. A., MSc PhD, 28 Wright St, Bentleigh, SE14	1959
Bermingham, Anne, BSc, 23 Walstab St, E. Brighton, S6	1958
Bird, E. C. F., MSc PhD, Australian National University, PO Box 197, Canberra, ACT	1961
Blackwood, Sir Robert R., MCE BEE, MIE, 8 Huntingfield Rd, Brighton, S5	1957
Bourke, D. O. N., 141 South Rd, Brighton, S5	1964
Boutakoff, N., DSc *Louvain*, Princess St, Kew, E4	1950
Brack, L. J., BCE, 14 Henham St, E. Hawthorn, E3	1960
Braithwaite, H. A., PhC FPS, 8 Kasouka Rd, Camberwell, E6	1958
Brazenor, C. W., 'Noonameena', Yarra Glen Rd, Healesville	1931
Brennan, D. J., 'Edelweiss', Buangor	1963
Brenton, W. G., BSc, DipEd, PO Box 99, Kyneton	1963
Briner, G. P., MSc PhD, 32 Latham St, E. Bentleigh, SE15	1963
Broadhurst, E., MSc, 457 St Kilda Rd, Melbourne, SC2	1930
Brown, A. G., BA *Cantab*, MRCS *Eng.* LRCP *Lond.* MIBiol, 'Narroghit', Elliminyt, Colac	1958
Brown, Prof. R. D., MSc PhD, 19 Denman Av., Balaclava, S16	1960
Brunn, T. H., 605 Malvern Rd, Toorak, SE2	1953
Brunnschweiler, R. O., PhD *Zurich*, 101 Jervois St, Deakin Heights, Canberra, ACT	1959
Bryant, R. L., Physics Dept, Monash University, Clayton	1964
Bunyan, J., PRMS LDS RCS *Eng.*, 22 Seymour St, Portman Sq., London, W.1	1959
Burnet, Prof. Sir Macfarlane, OM, MD PhD ScD DSc, FRACP FRS FAA, Walter and Eliza Hall Institute, PO, Royal Melbourne Hospital	1959
Burns, A. N., MSc, FRES, National Museum of Victoria, Russell St, Melbourne, C1	1957
Butcher, A. D., MSc, Fisheries and Wildlife Dept, 605 Flinders St, W. Melbourne, C3	1936
Byrne, J. M., PhC FPS, 11 Mitchell Rd, Caulfield, SE7	1963
Campbell, K. S. W., MSc PhD, Geology Dept, Australian National University, Box 4 GPO, Canberra, ACT	1964
Canavan, F., MSc, Essington Lewis House, 500 Bourke St, Melbourne, C1	1936
Candler, C., MA *Cantab*, Bendigo Technical College, Bendigo	1964
Cane, R. F., DSc *Tas.*, FRACI, 12 Alicia St, Hampton, S7	1961
Carlos, G. C., 21a Crosbie Rd, Murrumbeena, SE9	1951
Caro, Prof. D. E., MSc PhD, Dept of Physics, University, Parkville, N2	1961
Carr, Prof. D. J., MSc PhD, Botany Dept, Queen's University, Belfast, N. Ireland	1957
Casey, D. A., MC, FSA, 'Willimi', Cheniston Rd, Mt Macedon	1932
Cherry, Prof. T. M., BA PhD ScD, FRS FAA, University, Parkville, N2	1930
Chinner, J. H., BSc *Oxon* and *Melb.*, DipFor, Forestry Dept, University, Parkville, N2	1950
Chipman, H. C., ISO, LLB, 35 Spencer St, Essendon, W5	1958
Clark, G. C. L., CMG MC, BSc DEng, MME, Gold Mines of Australia Ltd, PO Box 860K, Melbourne, C1	1931
Clarke, E. R. H., MB BS BSc, DipCivEng, 127 Don St, Bendigo	1960
Cochrane, G. R., MA BSc, Geography Dept, University, Parkville, N2	1964
Collins, A. C., 9 Olympic Av., Newtown, Geelong	1928
Costello, J., Flat 6, 23-25 St Leonards Crt, South Yarra, SE1	1963
Coulson, A., MSc BEd, 56 Parkway, Yallourn	1929
Coutts, P. J. F., MSc BEE, Flat 6-3, Wellesley St, Hawthorn, E2	1965
Cowley, Prof. J. M., PhD DSc, FAA, Physics Dept, University, Parkville, N2	1963
Cowling, S. J., BSc (For), 22 Evan St, Parkdale, S12	1965
Cox, L. B., MD BS, MRCP, 241 St Kilda Rd, Melbourne, SC2	1946
Crespin, Irene, BA DSc, FRMS, Bureau of Mineral Resources, Turner, Canberra, ACT	1919
Crook, K. A. W., MSc PhD, Geology Dept, Australian National University, Box 4 GPO, Canberra, ACT	1964
Crow, R. K., JP SMIRE, 20 Parker St, Ormond, SE9	1958
Cuming, B. D., PhD, Grove St, Vermont	1959
Cuming, M. A., BSc, DIC FRACI, 65 William St, Melbourne, C1	1958
Curphey, A. N., OBE FSS *Eng.*, 45 Narrak Rd, Balwyn, E8	1958
Currey, D. T., BSc, 61 Sylvander St, N. Balwyn, E9	1948

Dare, G. K., 13 Byrne Av., Elwood, S3	1964
Davies, Mrs E. M., 7 Collinson Close, 57 Milan St, Mentone, S11	1956
Davis, Capt. J. K., 'Dundrennan', 492 St Kilda Rd, Melbourne, SC2	1920
Day, P. L., BSc, School of Mines, Ballarat	1962
Dean, The Hon. Sir Arthur, LLM, Wilks Av., Malvern, SE4	1958
Derham, Mrs F. T., BAgrSc MSc *Lond.*, Chemistry Dept, University, Parkville, N2	1959
Dixon, Miss J. M., BSc (Hons), National Museum, Russell St, Melbourne, C1	1965
Doery, Miss Mary K., BSc, DipEd, 20 Tower St, Mont Albert, E10	1964
Dorman, F. H., MA MSc PhD, 4 Joseph St, Lower Templestowe	1958
Dorward, D. F., BSc DPhil, Zoology Dept, Monash University, Clayton	1964
Douglas, J. G., MSc, 76 Sunhill Rd, Mt Waverley	1957
Douglas, G. W., BAgrSc, Lands Dept, 226 Clarendon St, Melbourne, C2	1960
Down, Mrs M. R., BAgrSc, 177 Copeland Rd, E. Beecroft, N.S.W.	1942
Downes, M. C., BSc, 'Talinga', Allens Rd, Heathmont	1962
Downes, R. G., MAgrSc, Soil Conservation Authority, 378 Cotham Rd, Kew, E4	1961
Drummond, F. H., BSc PhD, Zoology Dept, University, Parkville, N2	1933
Ducker, Mrs S. C., MSc, Botany Dept, University, Parkville, N2	1959
Duigan, Suzanne L., MSc PhD, 33 Morrah St, Parkville, N2	1957
Duke, J. R., BSc, 32 Damon Rd, Mt Waverley	1961
Dungan, R. W., MB BS, 117 Millswyn St, South Yarra, SE1	1958
Dunn, R. A., AAA AAIS, 60 Mimosa Rd, Carnegie, SE9	1946
Dyason, Diana J., MSc, University, Parkville, N2	1960

Ealey, E. H. M., MSc PhD, Monash University, Clayton	1961
Earl, C. T., BCE AMIE *Aust.*, 46 Scott St, Essendon, W5	1961
Eddy, A. R., BScF MF *Calif*, ADipFor *Cres*, MIFA, Victorian School of Forestry, Creswick	1963
Edgar, Lt-General H. G., CB CBE, 21 Glen Rd, Toorak, SE2	1958
Eldridge, K. G., MSc, 39 Lafayette St, Traralgon	1960
Esserman, N. A., BSc, AInstP, 1 Wallangra Rd, Dover Heights, N.S.W.	1923

Fearn-Wannan, H. J., BSc, 2 Merle St, N. Blackburn	1958
Ferrier, J. M., Box 20, Coleraine	1960
Fethers, G. E., BVSc, 6 Nevis St, Camberwell, E6	1957
Fitts, Sir Clive H., Kt, MD, 14 Parliament Pl., Melbourne, C2	1945
Focken, C. M., BSc BME DPhil *Oxon* MS *Colorado*, 170 Randolph St, Sliema, Malta	1952
Forster, Prof. H. C., MAgrSc PhD, School of Agriculture, University, Parkville, N2	1954
Fox, F. A., DSc, FIM, 4 South Rd, Brighton, S5	1958
Freake, R., 117 Millswyn St, South Yarra, SE1	1961
Fry, E., BDSc DDSc *Muenster*, 67 Williams Rd, Windsor, S1	1961

Gallus, A., PhD *Budapest*, DJur *Szeged*, 2 Patterson St, Nunawading	1963
Garran, R. R., MSc PhD, FRACI, c/o ICIANZ, 2 Nicholson St, E. Melbourne, C2	1954
Gaskin, A. J., MSc, 13 Asling St, Brighton, S5	1941
George, A. M., BSc, 15a Kycamba Gr., Toorak, SE2	1963
Ghent, R. L. G., BSc PhD, Zoology Dept, Monash University, Clayton	1964
Gibbons, F. R., BSc, 'Sherbon', Arundel Rd, Park Orchards	1963
Gibbs, W., MSc, MS *MIT*, Bureau of Meteorology, Cr Drummond and Victoria St, Carlton, N3	1963
Gill, E. D., BA BD, FGS FRGS, National Museum of Victoria, Russell St, Melbourne, C1	1938
Gladwell, R. A., 10 Hopetoun Rd, Toorak, SE2	1938
Gloe, C., MSc, 9 Collins St, Mentone, S11	1944
Gnielinski, S., 18 Treesbank Av., Springvale	1961
Gordon, A., BSc, Marlborough St, Mont Albert, E10	1961
Gottlieb, L., DipMechE *Hamburg*, VDI, AMIMechE *Lond.*, AMIE *Aus*, AMAusIMM, 17 Laver St, Kew, E4	1958
Goudie, A. G., BAgrSc, Murchison Rd, Tatura	1941
Grant, K., BSc, 4 Henley Dr., Glen Waverley	1962
Griffiths, A. F., MB BS, 1451 Burke Rd N., E. Kew, E5	1961
Grounds, R., BArch, FRAIA FRVIA, 100 St Kilda Rd, Melbourne, SC1	1958
Grose, R. J., BScFor, ADipFor AMIFA, 5 Puerta St, Burwood, E13	1960
Grubb, P. L. C., BSc PhD, CSIRO Mineragraphic Investigations, University, Parkville, N2	1964
Gunson, Mary, MSc, Zoology Dept, University, Parkville, N2	1944

Hack, J. B., BSc, 414 Collins St, Melbourne, C1	1957
Harrison, M., OBE, JP, 3 Charles St, Kew, E4	1964
Hartley, Mrs T. W., 351 Glenferric Rd, Malvern, SE2	1956
Hartmann, N., c/o James Bell Machinery Co. Pty Ltd, 352 Macaulay Rd, Kensington, W1	1956
Hartung, Prof. E. J., DSc PhD, Lavender Farm, Woodend	1923
Haycraft, J. A., c/o Western Mining Corp. Ltd, 55 MacDonald St, Kalgoorlie, W.A.	1951
Head, W. C. E., BA, DipEd, High School, PO Box 127, Numurkah	1931
Hills, Prof. E. S., DSc PhD, FRS FAA, University, Parkville, N2	1928
Hird, B. J. W., DipCivEng, 15 Forster St, Mitcham	1963
Hocking, J. B., BSc (Hons), Flat 4, 44 Davis Av., South Yarra, SE1	1963
Hogan, T. W., MAgrSc, 100 Riversdale Rd, Hawthorn, E2	1947
Holdaway, E. A., BSc BEd, 9 Bardolph St, Burwood, E13	1957
Holland, R. A., 536 Toorak Rd, Toorak, SE2	1931
Holmes, A. J., BSc BEd, 7 Collett Av., Ringwood	1949
Horwill, Sir Lionel, Kt, BSc, ARSSc, Bar.-at-Law, 'Corowa', Corowa Court, The Esplanade, Mornington	1961
Jack, A. K., MSc, 49 Aroona Rd, Caulfield, SE7	1913
Jacka, F. J., PhD, 568 St Kilda Rd, Melbourne, SC3	1958
Jeffreys, R. B., BSc, FRACI, 3 Ultimo Court, Toorak, SE2	1961
Jenkin, J. J., MSc, Mines Dept, E. Melbourne, C2	1945
Jensz, R. L., Devon Rd, E. Doncaster	1961
Johnson, T. J. P., BA, DipEd, Private Bag 39, Hamilton	1964
Jones, K. A., BCom, 28 Scott St, Beaumaris, S10	1956
Jones, L. H. P., BAgrSc MSc PhD, Agriculture Dept, University, Parkville, N2	1948
Jones, N. L., 7 Kingston St, Hampton, S7	1963
Joyce, E. B., BSc, Geology Dept, University, Parkville, N2	1963
Kaufmann, G. A., BA, 165 Gremorne St, Richmond, E1	1958
Kelly, M., MD, 410 Albert St, E. Melbourne, C2	1962
Kempson, F. A., SMIRE, 14 Drummond St, Blackburn S.	1958
Kenny, J. P. L., BCE, 38 College St, Elsternwick, S4	1942
Kerruish, Mrs R. M., MSc, CSIRO Division of Plant Chemistry, PO Box 109, Canberra, ACT	1960
Kimpton, V. Y., 16 Lansell Rd, Toorak, SE2	1946
Kirkman, J. M., MBBS, 227 Charman Rd, Cheltenham, S22	1965
Klaric, R., 35 Hanover St, Brunswick, N10	1964
Kloot, N. H., MSc, 636 Gilbert Rd, Reservoir, N19	1964
Knight, J. L., BSc, Mines Dept, Melbourne, C2	1944
Knight, J. L., MSc, FRACI, 1 Barbara Av., Burwood, E13	1961
Lang, P. S., BAgrSc PhD, 'Titanga', Lismore	1938
Langdon, H. C. C., 411 Beach Rd, Beaumaris, S10	1954
Law, P. G., CBE, DAppSc MSc, FAIP, 568 St Kilda Rd, Melbourne, SC3	1946
Lee, F. M., BCE, MIE *Aust.*, 30 Churchill St, Mont Albert, E10	1958
Lee, Mrs H. M., MSc, 54 Fitzgibbon St, Parkville, N2	1957
Leeper, Prof. G. W., MSc, Chemistry Dept, University, Parkville, N2	1931
Leslie, A. J., BScFor, ADipFor, 37 Third St, Black Rock, S9	1958
Ley, J. B. K., BCE, AMICE, 30 Cosham St, Brighton, S5	1958
Liddy, J. C., BSc, 13 Churchill Gr., Hawthorn, E2	1959
Lindner, A. W., MSc, c/o AMOSEAS, Box 1086N, GPO, Brisbane, Q.	1959
Ling, J. K., BSc, CSIRO Wildlife Survey, PO Box 109 City, Canberra, ACT	1949
Link, A. G., 11 Albert St, Fawkner, N15	1963
Littlejohn, M., PhD, Zoology Dept, University, Parkville, N2	1960
Lynch, D. D., MSc, Inland Estates Commission, 125 Macquarie St, Hobart, T.	1950
MacCallum, Prof. Sir Peter, MC, MA MSc MB ChB DPH, 91 Princess St, Kew, E4	1925
Macpherson, J. Hope, MSc, National Museum of Victoria, Russell St, Melbourne, C1	1940
Manning, Mrs J. M., PhC MPS, 15 Riversdale Court, Hawthorn, E2	1960
Manning, N. C., BSc, PhC MPS, Victorian College of Pharmacy, Royal Pde, Parkville, N2	1960
Marshall, V. C., MB BSc, FRACS, Surgery Dept, University, PO, Royal Melbourne Hospital	1963
Martin, M. J., 5 Cooba St, Canterbury, E7	1957
Martin, Sir Leslie H., CBE, PhD *Cantab*, FRS FAA FInstP, Walpole St, Kew, E4	1959

Massola, A., FRAS, National Museum of Victoria, Russell St, Melbourne, C1	1956
Matheson, J. A. L., MBE, MSc PhD, MICE MIStructE, Monash University, Clayton	1960
Mathews, A. G., BSc, 465 Lygon St, N. Carlton, N4	1961
Matthaei, E., Microscopy Laboratory, University, Parkville, N2	1959
McAndrew, J., BSc PhD, CSIRO Mineragraphic Investigations, University, Parkville, N2	1953
McCausland, M. E. R., 15 Millicent St, Toorak, SE2	1953
McEvey, A. R., BA, National Museum of Victoria, Russell St, Melbourne, C1	1960
McLaren, A. C., BSc PhD *Cantab*, 2 Glenbrook Av., E. Malvern, SE5	1960
McLaughlin, R. J. W., MSc PhD *Cantab*, Geology Dept, University, Parkville, N2	1963
McLennan, Sir Ian M., KBE, BEE, c/o Broken Hill Pty Ltd, 500 Bourke St, Melbourne, C1	1960
McLister, H. D., 2 Lucan St, Caulfield, SE8	1959
McNally, J., MSc, 3 Arcadia St, Box Hill, E11	1950
Middleton, W. G. D., ADipFor *Cres*, 81 Wimmera St, Dimboola	1964
Miller, F. L., MPS, BSc PhD, Botany Dept, University, Parkville, N2	1962
Millikan, C. R., DSc, Plant Research Laboratory, Swan St, Burnley, E1	1941
Milne, Angela A., MSc PhD, University Women's College, Parkville, N2	1957
Mitchell, A., BAgrSc, 6 Grange Av., Canterbury, E7	1962
Mitchell, A. W. L., BSc, Timbertop CEGS, Mansfield	1946
Moore, K. B., 11 Mona Pl., South Yarra, SE1	1945
Morgan, D. G., BSc, DipEd, Secondary Teachers' College, University, Parkville, N2	1959
Morgan, W. G., BCE, 18 Nan St, Box Hill, E11	1961
Morrison, J. D., PhD DSc, FAA, CSIRO Division of Chemical Physics, Box 4331 GPO, Melbourne, C1	1958
Mulvaney, D. J., MA, History Dept, University, Parkville, N2	1957
Mumme, W. G., MSc, Division of Mineral Chemistry, CSIRO, Box 4331 GPO, Melbourne, C1	1963
Murray, Miss F. V., MSc, 13 Gaynor Court, Malvern, SE4	1964
Mushin, Rose, MSc PhD, Bacteriology Dept, University, Parkville, N2	1942

Neboiss, A., MSc, National Museum of Victoria, Russell St, Melbourne, C1	1957
Newnham, I. E., MBE, MSc, Chemical Research Lab., CSIRO, Box 4331 GPO, Melbourne, C1	1961
Nicholas, J. R., BSc BEd, MACE, 3 Victoria St, Moe	1964
Nielsen, Miss B. J., MSc, 45 Summerhill Rd, Glen Iris, SE6	1954
Norman, G. C., DFC, 'Mt Widderin', Skipton	1964
Nye, E. E., BSc, College of Pharmacy, 381 Royal Pde, Parkville, N2	1932
Nyoeger, E., 173 Lower Dandenong Rd, Mentone, S11	1963

Ollier, C. D., MSc, Geology Dept, University, Parkville, N2	1963
Olsen, C. O., BA, DipEd, Malayan Teachers' College, Glugor, Penang, Malaysia	1945
Orr, R. G., MA BCh, 9 Heyington Pl., Toorak, SE2	1935
Osborne, A. G. A., BAgrSc, 'Lowestoft', Warrandyte	1957
Osborne, N. A., 1 Matong Rd, Mt Eliza	1930
Owen, W. R., MSc PhD, ARACI, Victorian College of Pharmacy, 381 Royal Pde, Parkville, N2	1962

Paine, D. W. M., BScFor, 17 Loddon St, Box Hill, E11	1961
Parker, C. D., BSc, DipBact *Lond*, FRACS, 47 Outlook Dr., Eaglemont, N22	1957
Parry, R. H. G., BCE MESc PhD, 6 Pamela St, Mt Waverley	1959
Pedder, A. E. H., MA *Cantab*, Dept Geology, University of New England, Armidale, N.S.W.	1965
Perdrix, J. L., 43 William St, Box Hill, E11	1961
Perry, J. W., MRACP MCPA, 276 Walsh St, South Yarra, SE1	1961
Perry, T. M., BA PhD *ANU*, Geography Dept, University, Parkville, N2	1964
Pescott, R. T. M., MAgrSc, FRES MIBiol, Royal Botanic Gardens, South Yarra, SE1	1944
Peterson, G. T., PhC FPS, 59 East Boundary Rd, E. Bentleigh, SE15	1958
Philip, G. M., MSc PhD, Geology Dept, Univ. of New England, Armidale, 5N, N.S.W.	1955
Playford, Mary, MSc PhD *Cantab*, Geology Dept, University of Queensland, St Lucia, Q.	1959
Pollitt, J. H., 444 Dandenong Rd, Caulfield, SE8	1964
Potter, Sir W. Ian, BEc, 30 Sargood St, Toorak, SE2	1957
Preston, H. E., 47 Haig St, Box Hill S., SE11	1949
Purnell, W. E., FRACI, 30 Currajong Av., Camberwell, E6	1960

Rade, J., MSc, Flat 28A, 601 St Kilda Rd, Melbourne, SC2	1961
Radford, W. C., MBE, MA MEd PhD, 236 Belmore Rd, Balwyn, E8	1958
Rayner, J. M., BSc, FInstP, 5 Tennyson Cr., Forrest, Canberra, ACT	1957
Read, T. A., FSTC FRACI MAusIMM, 15 Chatfield Av., Balwyn, E8	1960
Rees, A. L. G., DSc PhD, CSIRO Division of Chemical Physics, Box 4331 GPO, Melbourne, C1	1956
Reid, J. T., Flat 1, 159 Cotham Rd, Kew, E4	1954
Resch, C. E., BSc PhD, 16 Bouverie St, Carlton, N3	1957
Richards, S. M., BSc (Hons) PhD, CSIRO Mineragraphic Investigations, University Parkville, N2	1964
Richardson, Mrs J. R., MA PhD, 16 Raven St, Kew, E4	1958
Rigby, J. F., BSc, Geology Dept, Newcastle University College, Tighe's Hill, 2N, N.S.W.	1953
Ritchie, J. A., Ocean Grove	1964
Robinson, G., BA *Cantab*, 1A Beach St, Surrey Hills, E10	1964
Rowney, G., BSc, 4 Riddle St, Bentleigh, SE14	1952
Rosenberg, D., BA *Oxon*, T. Nelson & Sons, 117 Latrobe St, Melbourne, C1	1964
Rule, A. A. N., MIR MSXT *Lond*, 12 The Crescent, Surrey Hills, E10	1964
Sandie, R. B., BCE MEngSc, AMIE *Aust.*, 25 Moselle St, Mont Albert N., E12	1965
Saunders, W. A. J., BSc (Hons), 224 Warragul Rd, Burwood, E13	1964
Sauve, N. B., 7 Mervyn Cr., Ivanhoe, N21	1955
Schleiger, N. W., BSc BEd, 1 Astley St, Montmorency	1949
Schofield, Prof. G. C., MD DPhil, Dept Anatomy, Monash University, Clayton	1964
Scott, A. R., BE, AMIE, 10 Verdant Av., Toorak, SE2	1958
Scurfield, G., BSc PhD, Div. Forest Products, CSIRO, Yarra Bank Rd, S. Melbourne, SC4	1963
Seeger, R. C., 56 Jenkins St, Northcote, N16	1946
Selby, B. A., BSc, ARACI, 19 Chesterfield Av., Malvern, SE4	1958
Simpson, H. P., 8 Knutsford St, Balwyn, E8	1948
Sinclair, A. Q., 19 Crest Av., Balwyn, E8	1959
Skinner, G., LLB, 111 Charles St, Prahran, S1	1960
Sklovsky, G. A., IngDoc, 69 Prospect Hill Rd, Camberwell, E6	1963
Slack-Smith, R. J., BSc, c/o Fisheries Dept, 108 Adelaide Terrace, Perth, W.A.	1960
Smith, E. H., DipAdelUniv, 17 Helwig Av., Montmorency	1963
Smith, L. H., MSc DPhil, FRACI, 36 Duke St, Kew, E4	1958
Somerset, H. B., MSc, MAIMM, c/o A.P.M. Ltd, 360 Collins St, Melbourne, C1	1957
Specht, R. L., MSc PhD, Botany Dept, University, Parkville, N2	1961
Spencer-Jones, D., BSc PhD, 31 Winmalee Rd, Balwyn, E8	1952
Spicer, P. O., 13 Riverside Av., N. Balwyn, E9	1946
Stevens, B. J. M., 117 Millswyn St, South Yarra, SE1	1961
Stewart, A. J., MSc, Bureau of Mineral Resources, Childers St, Turner, ACT	1961
Styles, D. F., BSc, AMIE *Aust.*, 14 John St, Blackburn	1958
Sullivan, W., 37 Strathallan Rd, Macleod	1943
Sutton, P. R. N., DDSc, LDS, 24 Wellington St, Brighton, S5	1959
Talent, J. A., MSc PhD, 114 The Boulevard, Essendon, W5	1955
Tattam, Assoc. Prof. C. M., PhD DSc, Geology Dept, University, Parkville, N2	1945
Taylor, D. J., MSc, 23 Westbourne St, Prahran East, S1	1961
Temple, P., 7 Monash St, Ascot Vale, W2	1962
Ternouth, S. T., BSc, DipEd, 50 Hatfield St, N. Balwyn, E9	1957
den Tex, Prof. E., PhD *Leyden*, State University, Leyden, Netherlands	1952
Thomas, D. E., DSc, FAA, Mines Dept, Melbourne, C2	1929
Thomas, F. J. D., BSc (Hons), ARCS, ICIANZ Biological Research Station, Croydon	1955
Thomas, G. A., BSc PhD, Geology Dept, University, Parkville, N2	1944
Thomas, H. F., PO Box 78, Irymple	1961
Thompson, G. D., AMIE *Aust.* HonMIBF *Lond.*, Royal Melbourne Institute of Technology, Latrobe St, Melbourne, C1	1959
Thompson, B., BSc, Mines Dept, Treasury Place, Melbourne, C2	1963
Thompson, G. T., 43 Weybridge St, Surrey Hills, E10	1953
Thomson, J. A., MSc, Zoology Dept, University, Parkville, N2	1958
Thomson, Prof. D. F., OBE, DSc *Melb* PhD *Cantab*, DipAnthrop *Cantab & Sydney*, Anthropology Dept, University, Parkville, N2	1958
Thorn, W., MEE MIE *Aust.*, 132 Canterbury Rd, Canterbury, E7	1958
Thrower, L. B., MSc, 23 Laver St, Kew, E4	1961

Timcke, E. W., 15 Faircroft Av., Glen Iris, SE6	1950
Tindale, B., FRMS, Yarra Junction	1951
Townsend, Prof. S. L., MD MS, FRCS *Edin.*, Obstetrics and Gynaecology Dept, University, Parkville, N2	1951
Tudehope, N. A., BSc, 22 St James Av., Mont Albert, E10	1960
Turner, Prof. J. S., MA PhD MSc, FAA, University, Parkville, N2	1938
Tylee, A. F. E., BE BSc, 31 Wingan Av., Camberwell, E6	1961
Tylee, A. N., Jindivick North	1951
Uhl, A. H., MIE *Aust.*, MIEE *Lond.*, MAIEE *N.Y.*, 1 Gwenda Av., Blackburn	1964
Vale, W. H., 17 Walstab St, E. Brighton, S6	1961
Verso, M. L., MB BS DTM&H, MCPA, Blood Bank, 114 Flinders St, Melbourne, C1	1962
Wadham, Prof. Sir Samuel, MA LLD, AgrDip, 220 Park St W., W. Brunswick, N12	1932
Wakefield, N. A., BSc, 30 Douglas St, Noble Park	1961
Walsh, R. W., BA, 64 Brown St, Heidelberg, N22	1964
Wark, I. W., CBE, PhD DSc, FAA, CSIRO, 314 Albert St, E. Melbourne, C2	1961
Warren, J. W., MA PhD, Zoology and Comparative Physiology Dept, Monash University, Clayton	1963
Watson, Mrs Jeanette E., 74 Nimmo St, Essendon, W5	1961
Weickhardt, L. W., MSc, FRACI, 125 Canterbury Rd, Canterbury, E7	1959
Wettenhall, H. N. B., MD BS, MRCP FRACP, 41 Spring St, Melbourne, C1	1959
White, Prof. M. J. D., DSc *Lond.*, FRS FAA, Zoology Dept, University, Parkville, N2	1958
White, R. K., FIPAA, 360 Collins St, Melbourne, C1	1958
Whiting, R. G., BME, 7 Barkly Ter., Mitcham	1959
Whitelaw, J. J., BME, 286 Huntingdale Rd, Chadstone, SE10	1963
Wickens, T. W., 27 Narrak Rd, Balwyn, E8	1957
Wilcock, A. A., BSc BEd, Geography Dept, University, Parkville, N2	1934
Williams, W. D., BSc PhD, FZS, Monash University, Clayton	1961
Willis, A. G., MSc, Zoology Dept, University, Parkville, N2	1949
Willis, J. H., BSc, 102 Male St, Brighton, S5	1964
Wilson, D., BSc, 46 Hoddle St, Essendon, W5	1961
Wiltshire, A. R. L., CMG DSO MC VD, 35 Evans Ct, Toorak, SE2	1955
Woodford, E. R., Flat 3, 'Winton', Linton Ct, E. Hawthorn, E3	1963
Woodruff, D. S., BSc, Trinity College, Parkville, N2	1965

COUNTRY MEMBERS

Adams, H. G. C., 'Danedite', Weerite	1945
Baldwin, J. G., BSc BAgrSc, 33 Walnut Av., Mildura	1949
Bishop, J. J., BA, High School, Moe	1950
Burn, R., 3 Nantes St, Newtown, Geelong	1956
Casey, Mrs D. A., 'Willimi', Cheniston Rd, Mt Macedon	1953
Condon, M. A., MSc, Bureau of Mineral Resources, Canberra, ACT	1937
Conley, W. R., 2 Lillian St, Nunawading	1956
Corney, Mrs A. D., BSc, 17 Ratho St, New Town, T.	1945
Dawes, L. F., BSc, 43 Hopetoun Gr., Ivanhoe, N21	1954
Dickins, J. MacG., MSc PhD, Bureau of Mineral Resources, Canberra, ACT	1952
Forrest, J. M., Metropolitan Farm, PO, Werribee	1954
Gaskin, A. J., MSc, 6 Burns St, Elwood, S3	1941
Glaessner, M. F., PhD DSc, FAA, Geology Dept, University of Adelaide, S.A.	1939
Gnielinski, S., Institute of Geography, Technical University Berlin-Charlottenburg, Ernst Reuther Platz, Western Berlin, Germany	1961
Hill, Prof. Dorothy, DSc PhD, FAA, Geology Dept, University of Queensland, St Lucia, Q.	1939
Hope, G. B., BME, 'Carrical', Hermitage Rd, Newtown, Geelong	1918
Kershaw, R. C., BSc, 45 West Tamar Rd, Launceston, T.	1956
Lindholm, J. D. E., c/o High School, Shepparton	1952
Massey, C. H., 11 Church St, Ashfield, N.S.W.	1957
McLaren, A. C., BSc PhD *Cantab*, 2 Glenbrook Av., E. Malvern, SE6	1960

McWhae, Mrs J. R. H., c/o California Standard Co., Medical Arts Bldgs, 329A 6th Ave SW, Calgary, Canada	1948
Murphy, H. D., Mornington	1950
Netherway, G. C., 606 Dana St, Ballarat	1958
Payne, T. E. N., 'Woodburn', Kilmore	1945
Searle, S. S., Metropolitan Farm, PO, Werribee	1954
Thomson, J. A., MSc PhD, Zoology Dept, University, Parkville, N2	1958
Yates, H., MSc, 102 Eyre St, Ballarat	1943

Associates

Anderson, R. E., BA, 20 Hudson St, Moonee Ponds, W4	1964
Autry, W. C., BSc, 1833-7th St Apt 1, Santa Monica, California, U.S.A.	1957
Baker, A. A., 53 Carlisle St, Preston, N18	1946
Bamford, W. E., BE (Hons), 190 Page St, Middle Park, SC6	1963
Bell, G., BSc, 62 Russell St, Surrey Hills, E10	1955
Bird, R. G., 'Hoana', Saltpan Bay, Prince Alfred Pde, Newport, Sydney, N.S.W.	1962
Boardman, Miss V. M., 3/262A Latrobe Ter., Geelong	1962
Boch, P. E., BSc, 32 Swayfield Rd, Mt Waverley	1957
Bollen, P. W., BSc, Flat 16, 21 Bruce St, Toorak, SE2	1957
Bowen, K. G., 2 Taylor St, Montmorency	1964
Bowler, J. M., MSc, Geology Dept, University, Parkville, N2	1960
Brine, F. W., 'Taunton', Oakdene Court, Mt Waverley	1964
Brunn, Mrs T. H., 605 Malvern Rd, Toorak, SE2	1960
Burns, D., 11 Robertson St, Colac	1960
Buttery, S. H., 146 Highfield Rd, Camberwell, E6	1952
Carr, Mrs D. J., MSc, Queen's University, Belfast, N. Ireland	1937
Carter, A. N., MSc PhD, 8 Scott St, Maroubra Bay, N.S.W.	1947
Clarke, W. G., BE BSc, DipEd, 67 Willis St, Hampton, S7	1957
Clifford, H. T., MSc PhD, Botany Dept, University of Queensland, St Lucia, Q.	1949
Coats, R. P., BSc, South Australian Dept of Mines, 168 Rundle St, Adelaide, S.A.	1951
Cobbett, A. M., Oxford Close, Moorabbin, S20	1951
Cochrane, G. W., MSc, 320 Lane St, Broken Hill, N.S.W.	1945
Colledge, Miss Jean S., 51 Through Rd. Burwood, E13	1964
Cormak, M. G., Lower Crawford, Private Bag 39, PO, Heywood	1961
Couper, J. K., FRMIT, 64 McIndoe Pde, Parkdale, S12	1965
Court, A. B., BSc, National Herbarium, Royal Botanic Gardens, South Yarra, SE1	1949
Crawford, T. W., 1 Belgrave Av., Balwyn, E8	1964
Darragh, T. A., BSc, DipEd, 46 The Esplanade, Clifton Hill, N8	1963
de Jonk, B. T. R., 21 Mall Court, Blackburn N.	1964
Dempster, Miss P. B., BSc, c/o 751 Canterbury Rd, Surrey Hills, E10	1957
Elford, F. G., BSc BEd, 76 New St, Brighton, S5	1929
Elmore, L. K. M., PO Box 317, Hamilton	1964
English, J. R., 302 Lower Heidelberg Rd, E. Ivanhoe, N21	1956
Esplan, W. A., BSc, 37 Barnes Av., Burwood, E13	1951
Finlay, Miss C. F., BSc, Geology Dept, University, Parkville, N2	1950
Fisher, Eileen E., PhD, 1 Balwyn Rd, Canterbury, E7	1949
Frostick, A. C., 12 Power St, N. Williamstown, W16	1933
Gale, J. C., 154 Mont Albert Rd, Canterbury, E7	1959
Gamble, D. S., Ormond College, College Cr., Parkville, N2	1964
Gostin, V. A., BSc, 92 Marlborough St, E. Bentleigh, SE15	1963
Hewett, D. C., BSc, DipEd, 77 Agg St, Newport, W15	1959
Hounslow, A. W., BSc, 28 Georgiana St, Sandringham, S8	1958
Johns, M. W., BSc, 355 Upper Heidelberg Rd, Ivanhoe, N21	1958
Kenley, P. R., BSc, 14 Yarrabee Ct, Mt Waverley	1948
Lawrence, C. R., BSc, 3 Wright St, Bentleigh, SE14	1958
Learmonth, A. P., BSc, 12 Cornwall Rd, Sunshine, W20	1955
Lord, E. E., GPO Box 5278, Melbourne, C1	1950

McLaurin, A. N., Couangalt, via Gisborne	1963
McLennan, Assoc. Prof. Ethel, DSc, Botany Dept, University, Parkville, N2	1915
Marsden, M. A. H., BSc, 17 Oak St, Beaumaris, S10	1952
Matthaei, Mrs G., 146 Gatehouse St, Parkville, N2	1959
Moir, Mrs Marion M., MA, DipEd, 434 Elgar Rd, Box Hill, E11	1960
Mooney, M. J., 'Beann Nhairi', Yarra Junction	1963
Moore, B. R., BSc, Peter St, Eltham	1957
Morris, P. F., 6 Mandeville Cr., Toorak, SE2	1921
Neilson, J. L., BSc, 1 Fordham Av., Camberwell, E6	1952
Nicholas, T., Bureau of Mineral Resources, Canberra, ACT	1958
Nicholson, B. M., BAgrSc, Soil Conservation Authority, Box 187 PO, Bairnsdale	1963
Passioura, J. B., MSc PhD, 28 Meredith St, Elwood, S3	1961
Pinches, Mrs M., 140 Churchill Highway, Braybrook, W19	1943
Pretty, R. B., MSc, Private Bag, Cobargo, N.S.W.	1922
Pringle, J. V., 422 Waverley Rd, E. Malvern, SE5	1961
Rash, K. E., 75 Humffray St S., Ballarat	1960
Rawlins, R. J., BSc, c/o PO, Cloncurry, Q.	1957
Reed, K. J., BSc, 5 Premier Av., Mitcham	1958
Richards, S. M., BSc (Hons) PhD, Geology Dept, Stanford University, Stanford, California, U.S.A.	1964
Rimington, K. N., BSc, 15 Yuille St, Brighton, S5	1948
Shaw, H., 16 Douglas Av., Box Hill S.	1956
Sherrard, Mrs H. M., MSc, 43 Robertson Rd, Centennial Park, N.S.W.	1918
Simpson, B., 3 Knutford St, Balwyn, E8	1959
Singleton, O. P., MSc PhD, Geology Dept, University, Parkville, N2	1943
Sinnott, P. J., 17 Normdale Rd, E. Bentleigh, SE15	1959
Squance, G. J., 14 Rupert St, E. Brunswick, N11	1963
Stubbs, D., 2 Coleridge St, Elwood, S3	1960
Taylor, T. W., Dept of Works, C/o George Nemel's Survey Party, Darwin, N.T.	1963
Tuddenham, W. G., BSc, DipEd, Geography Dept, University of Sydney, N.S.W.	1963
Valiullah, M., MSc, Geology Dept, University, Parkville, N2	1962
Vandenberg, A. H. M., 6 Fren Av., Frankston	1965
Vasey, G. H., BCE, University, Parkville, N2	1936
Walker, A. L., Chemistry Dept, University, Parkville, N2	1961
Walsh, Mrs A., 64 Brown St, Heidelberg, N22	1964
Watts, H. A., 15 Tower Hill Rd, Glen Iris, SE6	1954
White, O. L., BSc MASc, Dept of Civil Engineering, University of Waterloo, Waterloo, Ontario, Canada	1955
Whitehead, Mrs R., MSc, 58 Invermay Gr., Rosanna	1942
Wilkins, R. W. T., MSc, Dept Mineralogy and Petrology, University of Cambridge, U.K.	1961
Wilkinson, H. E., 20 Ruthven St, W. Macleod	1965
Williams, G. E., MSc, Sedimentology Research Laboratory, Whiteknights Park, Reading, Berks, U.K.	1962
Wymond, A. P., MSc, CSIRO Division of Forest Products, PO Box 18, S. Melbourne, SC4	1951

Royal Society of Victoria

ANNUAL REPORT OF THE COUNCIL FOR 1964

The President and Council present to members of the Society the Annual Report with Financial Statement for the year 1964.

The following meetings of the Society were held:

MARCH 12—ANNUAL MEETING. The following office-bearers were elected:

President—Mr R. T. M. Pescott.
Vice-Presidents—Mr J. H. Chinner and Associate Professor C. M. Tattam.
Honorary Secretary—Mr E. D. Gill.
Honorary Treasurer—Mr L. Adams.
Honorary Librarian—Associate Professor C. M. Tattam.
Honorary Assistant Secretary—Dr D. Spencer-Jones.

The following Members of Council were elected:

Mr H. C. Chipman, Dr J. D. Morrison, Dr C. E. Resch, Mr A. G. Willis, Professor J. Andrews, and Dr P. G. Law.

The following continued in office:

Mr V. G. Anderson, Dr B. D. Cuming, Captain J. K. Davis, Dr R. R. Garran, Professor G. W. Leeper, and Professor J. S. Turner.

Upon conclusion of the Annual Meeting an ORDINARY MEETING was held, when Dr P. G. Law gave a lecture on 'Icebergs'.

APRIL 9—In the presence of His Excellency the Governor of Victoria and Patron of the Society, Major-General Sir Rohan Delacombe, KCMG KBE CB DSO, Dr P. A. Siple spoke on 'Where scientific research is leading us'.

MAY 14—LECTURE by Professor J. G. D. Clark of Cambridge University on 'Archaeology, prehistory and society'.

JUNE 11—LECTURE and DEMONSTRATION by Dr B. D. Cuming on 'Plastics'.

JULY 9—RESEARCH PAPERS by Dr Isabel Cookson, Professor J. W. Valentine, Dr F. C. Beavis, Dr W. B. N. Berry, Mr T. A. Darragh, and Mr J. H. Willis and Mr E. D. Gill.

AUGUST 13—LECTURE by Professor Donald F. Thomson on 'The Second Bindibu Expedition'.

SEPTEMBER 10—The 1964 Research Medal was presented to Dr G. J. V. Nossal of the Walter and Eliza Hall Institute for Medical Research. Dr Frank Hirst lectured on 'Computers and their application'.

OCTOBER 8—LECTURE by Mr G. Robinson on 'Some recent developments in geomorphology'.

NOVEMBER 12—SOIREE. Following a reception and viewing of exhibits, colour films by Mr R. G. B. Skinner on Singapore, Malaya, Penang, and Thailand were viewed.

DECEMBER 10—Professor Sir Samuel Wadham and Mr D. A. Casey were appointed auditors. RESEARCH PAPERS were presented by Dr M. L. Verso, Dr Isabel Cookson, Mr B. R. Moore, Mr J. Couper, Dr P. S. Hossfeld, Mr A. Massola, Dr B. McGowran, Mr A. E. H. Pedder, Dr G. M. Philip, and Mr D. J. Taylor.

The number of members at 31 December 1964 was Honorary 3, Life Members 21, Members 324, Associates 76, and Country Members 21, making a total of 445. This is a record figure for membership and 30 more than the previous year. During the year 2,496 volumes and parts were added to the library.

Attendances at Council meetings were Mr Adams 6, Mr Anderson 10, Professor Andrews 4, Mr Chinner 2, Mr Chipman 2, Dr Cuming 4, Captain Davis 5, Dr Garran 9, Mr Gill 10, Dr Law 3, Professor Leeper 8, Mr Pescott 9, Dr Resch 9, Dr Spencer-Jones 9, Professor Tattam 9, Professor Turner 1, Mr Willis 1. Mr Adams, Mr Chinner, Dr Law, Dr Morrison, and Professor Turner were overseas for part of the year.

The Society deeply regrets the loss during the year of the following members:

BENJAMIN GEORGE GATES, BSc PhD, ACGI DIC MIEE MIEAust. was born in England in 1904 and died on 1 December 1964 at a retirement dinner given by his colleagues of the Royal Commonwealth Society in Melbourne. He graduated from the City and Guilds College of the University of London in 1924. After serving with various industrial organisations, he joined the Radio Department of the Royal Aircraft Establishment at Farnborough in 1935, his most noteworthy research project being that of speech modulation of the radio transmitter to provide communication in the high noise levels encountered between aircraft and ground controls. He left R.A.E. in 1950 as Head of his Department, to become Controller in Australia of the Long Range Weapons project of the Australian Defence Scientific Service. His name is associated with planning and building Woomera, with the British Army's anti-tank weapon 'Malkara', and with 'Ikara', a guided weapon project for the Royal Australian Navy. He had been a member of the Royal Society of Victoria since 1958.

DENZIL ISIDRO HARTLEY was born in Melbourne on 17 October 1900 and died there on 9 December 1964. He was a trustee of the Kelvin Club and did a great deal to develop that organization. His outstanding scientific contribution was the organization of the Malacological Society of Australia of which he was president from 1956 to 1964. With the co-operation of his wife, he established the Society and, under his leadership, it grew to 480 members with four Australian branches and many overseas members. In order to publish original work, the *Journal of the Malacological Society of Australia* was established, and eight volumes were published. Just before his death, Denzil Hartley negotiated the transfer of the headquarters of the Society to Sydney. He had been a member of the Royal Society of Victoria since 1956.

ROBERT LOCKHART JACK, BE DSc, FGS was born at Townsville, Queensland, in January 1878, and died in Tasmania on 23 October 1964. He obtained his degree in mining engineering at the Sydney University, following which he was associated with his father, Dr Robert Logan Jack, as consulting mining engineers. In this capacity, he worked from 1899 to 1904 investigating mineral deposits in China and in many parts of Europe and South Africa. Returning to Australia in 1906, he joined the Golden Horseshoe Gold Mine, Kalgoorlie, as assistant surveyor and geologist. In 1912 he joined the South Australian Department of Mines as Assistant Government Geologist, remaining with that Department for 19 years, during which time he became Deputy Director. The number, diversity, and quality of his publications which were written during this period were outstanding and, in recognition, he was awarded a Doctorate of Science by the Adelaide University in 1930. He joined The Broken Hill Pty Co. Ltd in April 1931, and became a member of the Royal Society of Victoria in the same year. Shortly after, he became the Company's Chief Geologist, which position he retained until his retirement in February 1948 after 17 years' service.

WILLIAM BOARDMAN, MSc was born at Manchester, England, on 2 June 1906 and was brought to Australia at an early age. He took part in the British Barrier Reef Expedition to the Low Is. (1928-29) and subsequently worked in the Australian Museum, Sydney in the Departments of Invertebrates (1930-35) and Birds and Reptiles (1935-38). He obtained his MSc degree at Sydney University at the age of 37 while attached to the Commonwealth Department of Health as a vertebrate zoologist. Subsequently he held lecturing appointments at Canberra University College (1944) and in the Universities of Queensland (1945-47) and Melbourne (1947-63). He will be remembered by generations of Melbourne medical graduates for his well organized and conscientious teaching of pre-medical biology. Boardman published several research papers, mainly upon Australian oligochaetes and marsupials. His early work was morphological and systematic. He later learned techniques of skin-grafting from Professor P. B. Medawar and, from 1950 onwards, he applied this to the study of skin morphogenesis in the rat. He was a member of the Linnean Society of New South Wales, the Royal Zoological Society of New South Wales, and the Royal Society of Queensland; he was elected to the Royal Society of Victoria in 1947. William Boardman died in Melbourne on 28 November 1963.

RONALD WILLIAM TRAFFORD COWAN, MA BLitt was an Adelaide graduate in arts and won a Rhodes Scholarship from Adelaide. He came to Melbourne in 1946 to be Warden of Trinity College at the University of Melbourne. He became a member of the councils of Melbourne and Monash Universities and was closely associated with other educational organizations. He joined the Royal Society of Victoria in 1959 and remained a member until his death on 26 June 1964.

TREASURER'S REPORT

During the year, the cost of publishing Proceedings continued to rise in line with other rising costs. However, increasing lettings assisted in offsetting some of these costs.

The Society expresses its appreciation to the State Government for its grant and to those others shown in the Financial statements who gave so much help to the Society.

SUMMARY FOR YEAR ENDED 31 DECEMBER 1964

		£	s.	d.
Balance from 1963		£1,389	10	4
Total Receipts		12,211	12	11
		£13,601	3	3
Total Payments		12,640	3	9
	Cr.	£960	19	6

INVESTMENTS HELD AS AT 31 DECEMBER 1964

Australian Guarantee Corporation Limited— 7% Debenture Stock	£150
Australian Aluminium Company Limited— 7% Debenture Stock	800
Bitumen & Oil— 8% Registered Unsecured Notes	100
Industrial Acceptance Corporation— 7% Registered Unsecured Notes	4,000
Finance Corporation of Aust. Limited— 6½% Registered Unsecured Notes	900
	£5,950

FINANCIAL STATEMENT FOR YEAR ENDED 31 DECEMBER 1964

RECEIPTS

Balance brought forward 1/1/64				£1,389	10	4
Subscriptions				1,669	1	11
Rents				999	19	6
Sale of Publications				1,612	6	10
Interest—						
Investments	£297	11	7			
Benefactions	269	0	0	566	11	7
Benefactions—						
Estate of the late Dr F. L. Stillwell				4,000	0	0
Grants and Donations—						
Government of Victoria—						
Annual Grant	£800	0	0			
Towards cost of plates	208	0	0			
University of Melbourne	550	0	0			
” ”	104	0	0			
Delhi Australia Petroleum Ltd	10	0	0			
Mobil Oil Australia Ltd	50	0	0			
J. Mahoney	10	0	0			
Dept of Mines, Victoria	182	0	0	1,914	0	0
Investments—						
A.G.C. 7% Debenture Stock				850	0	0
New Library Building Fund				50	10	0
Sundry Receipts—						
Hallkeeping Refund	£99	12	6			
Telephone Refund	5	18	2			
Postage Refund	1	12	9			
Sale of Blocks	3	6	6			
Received from RCOG	438	13	2	549	3	1
				£13,601	3	3

PAYMENTS

Salaries—						
Assistant Editor	£31	10	0			
Assistant Librarian	220	4	6			
Clerical	174	1	4			
Hallkeeping	453	15	11	£879	11	9
Publishing (*Proceedings* Vol. 77 Parts 1 & 2)				5,262	11	1
Stationery				104	3	4
Telephone				89	1	1
Electricity				351	1	8
Rates				60	10	6
Repairs and Maintenance				760	14	11
Postages				108	18	7
Investments—						
Industrial Acceptance Corporation	£4,000	0	0			
Finance Corporation Australia	900	0	0	4,900	0	0
Sundries—						
Bookbinding	£63	0	0			
CSIRO Index	3	0	0			
Insurance	55	19	4			
Refund of Subscription	1	11	6	123	10	10
Total Payments				£12,640	3	9
Balance carried forward 31/12/64				960	19	6
				£13,601	3	3

L. ADAMS, *Hon. Treasurer*

Audited and found correct—

D. A. CASEY } *Hon.*
R. R. GARRAN } *Auditors*

INDEX